Astronomy
special issue

25-page info-packed 2004 Sky Guide of celestial events

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# *Explore the* UNIVERSE®

10TH ANNIVERSARY EDITION 2004

Display until December 31, 2003

COSMIC DISTANCE SCALE

## Fantastic voyage

From the tiny to the infinite

SOLAR SYSTEM OBSERVING

## Comet NEAT, better than Halley

EDITORS REVIEW

## 25 hot new products

TECHNIQUES

## OK — I got a telescope, now what?

PROFESSIONAL ASTRONOMY

## Ground-based vs. space-based scopes

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C10-N
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C8-S
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C6-RGT
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|---|---|---|---|---|---|---|---|---|
| **Optical Design** | 102mm (4.0") refractor | 127mm(5") Schmidt-Cassegrain | 150mm (6.0") reflector | 150mm (6.0") refractor | 203mm (8") Schmidt-Cassegrain | 200mm (8.0") reflector | 235mm (9.25") Schmidt-Cassegrain | 254mm (10") reflector |
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| **Finderscope** | 6x30 | 6x30 | 6x30 | 9x50 | 6x30 | 9x50 | 6x30 | 9x50 |
| **Mount** | CG-4 Equatorial | CG-5 Equatorial | CG-4 Equatorial | CG-5 Equatorial | CG-5 Equatorial | CG-5 Equatorial | CG-5 Equatorial | CG-5 Equatorial |
| **Eyepiece** | 1-1/4" – 20mm (50x) | 1-1/4" – 25mm (50x) | 1-1/4" – 20mm (38x) | 1-1/4" – 20mm (60x) | 1-1/4" – 25mm (81x) | 1-1/4" – 20mm (50x) | 1-1/4" – 25mm (94x) | 1-1/4" – 20mm (60x) |
| **Star Diagonal** | 1-1/4" | 1-1/4" | n/a | 1-1/4" | 1-1/4" | n/a | 1-1/4" | n/a |
| **Accessory tray** | yes | yes | yes | yes | yes | yes | yes | yes |
| **Tripod** | Aluminum | 2" Stainless Steel | Aluminum | 2" Stainless Steel | 2" Stainless Steel | 2" Stainless Steel | 2" Stainless Steel | 2" Stainless Steel |
| **CD ROM** | The Sky Level 1 | The Sky Level 1 | The Sky Level 1 | The Sky Level 1 | The Sky Level 1 | The Sky Level 1 | The Sky Level 1 | The Sky L1 |

## Additional Specifications — Computerized Models

| | |
|---|---|
| **Hand Control** | Double line, 16 character Crystal Display; 19 fiber optic backlit LED buttons |
| **Motor: Type** | DC Servo motors with encoders, both axes |
| **Max Slew Speed** | 4°/second |
| **Software Precision** | 24bit, 0.08 arcsec calculation |
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| **Motor Ports** | Aux Port, Autoguide Ports |
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C5-SGT
[11072]

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[11026]

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*Explore the* **UNIVERSE** 10TH EDITION – 2004

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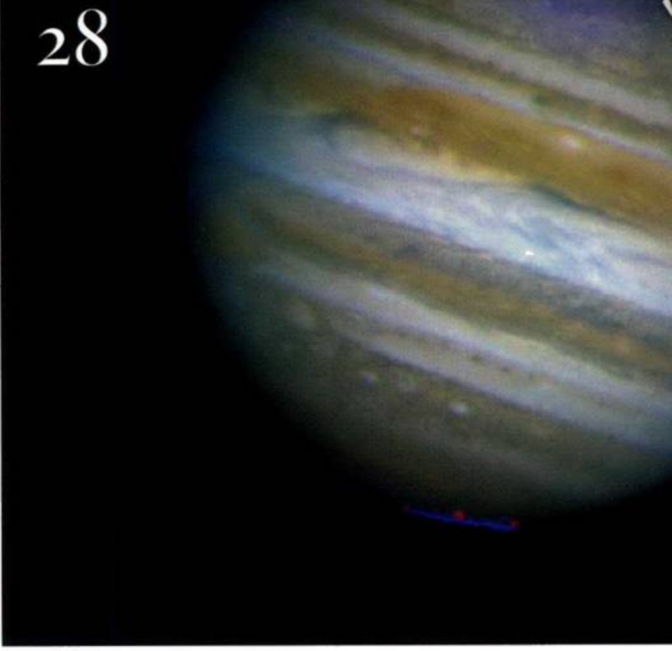

NASA ET AL.

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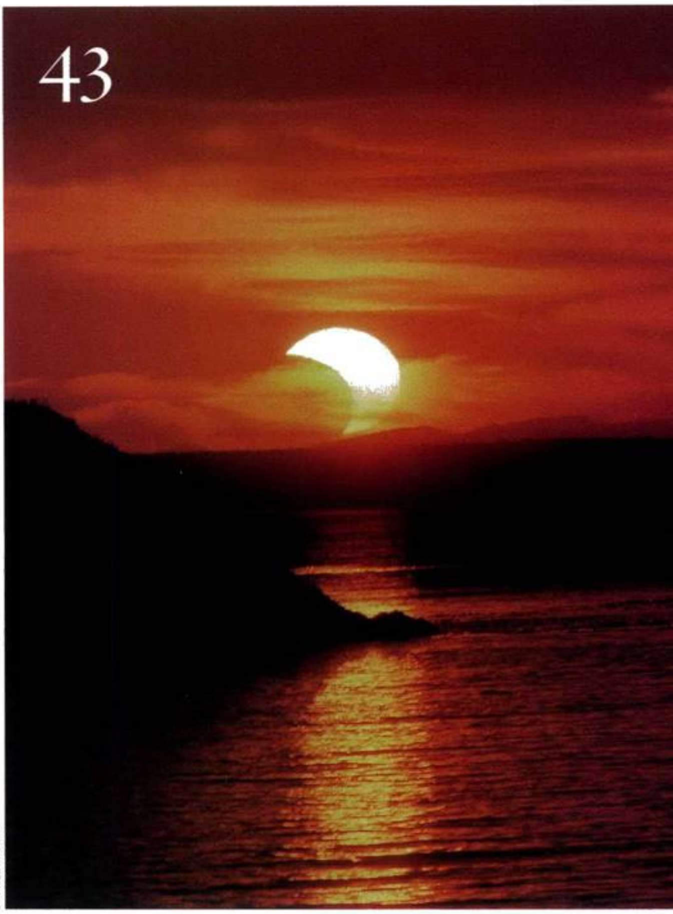

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25 hot new products
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Ground-based vs. space-based scopes

### ON THE COVER

The Andromeda Galaxy (M31) blazes with the light of hundreds of billions of stars. Located 2.7 million light-years away, this bright spiral, which is the largest in the Local Group, is visible to the naked eye.
ROBERT GENDLER

# at the eyepiece

## Finding your way through the darkness

**The problem with numbers is that — except for a very comfortable few — they fail us. Everyone knows that a person is a couple of meters high, that a tree stands ten or twenty or thirty meters tall. But we live in one thin slice of the universe, stuck on Earth's surface, never venturing into the realm of the very large or the very small.**

How big are galaxies or the distances between galaxies? How small the size of a hydrogen atom? Such things seem just beyond the mental comfort range of the human imagination.

Enter "Getting a grip on the universe" (page 7), an ambitious, three-part story by astronomers Hendrik Schatz, Chris Laws, and Pamela Gay. As the authors explain, cosmologists normally deal with very large things like planets, stars, and galaxies, but they also need to comprehend and explain the behaviors of miniscule things like DNA, atoms, and electrons. Three major stories go hand-in-hand to paint a picture of the cosmos in our minds: the creation of the elements, making stars and planets, and the nature of galaxies. These tales, taken together, weave a coherent picture of the sizes of everything in the universe.

Another conundrum that confronts us is what exactly to look at in that great infinite sky. Contributing editor Robert Burnham's story "I have a scope, now what do I do?" (page 34) tackles the problem with suggestions about what to look at to make the most of owning a small telescope. Whether your tastes lean toward the Moon and planets or distant, deep-sky gems, you will find sage advice from a longtime observer in the pages of this story.

Wondering which night to observe those celestial wonders? Terry Dickinson, editor of the Canadian magazine *Sky News*, contributes a terrific guide to choosing a night and an observing site that will make the most of your scope. In his "Good site + good night = observing joy" (page 70), Dickinson explains the basics of what makes for good observing opportunities both in terms of atmospheric steadiness and localized ground conditions. It's a valuable read.

Finally, don't miss contributing editor Phil Harrington's extensive "25 hot new products" (page 74) — a superb guide to the greatest new telescopes and accessories on the market. Whether you're looking for a first telescope, want to move up to a new one, or are looking to spice things up with accessories, this article will serve you well.

Yours truly,

**DAVE EICHER**
*Editor*

*Explore the* **UNIVERSE.**
10th EDITION - 2004

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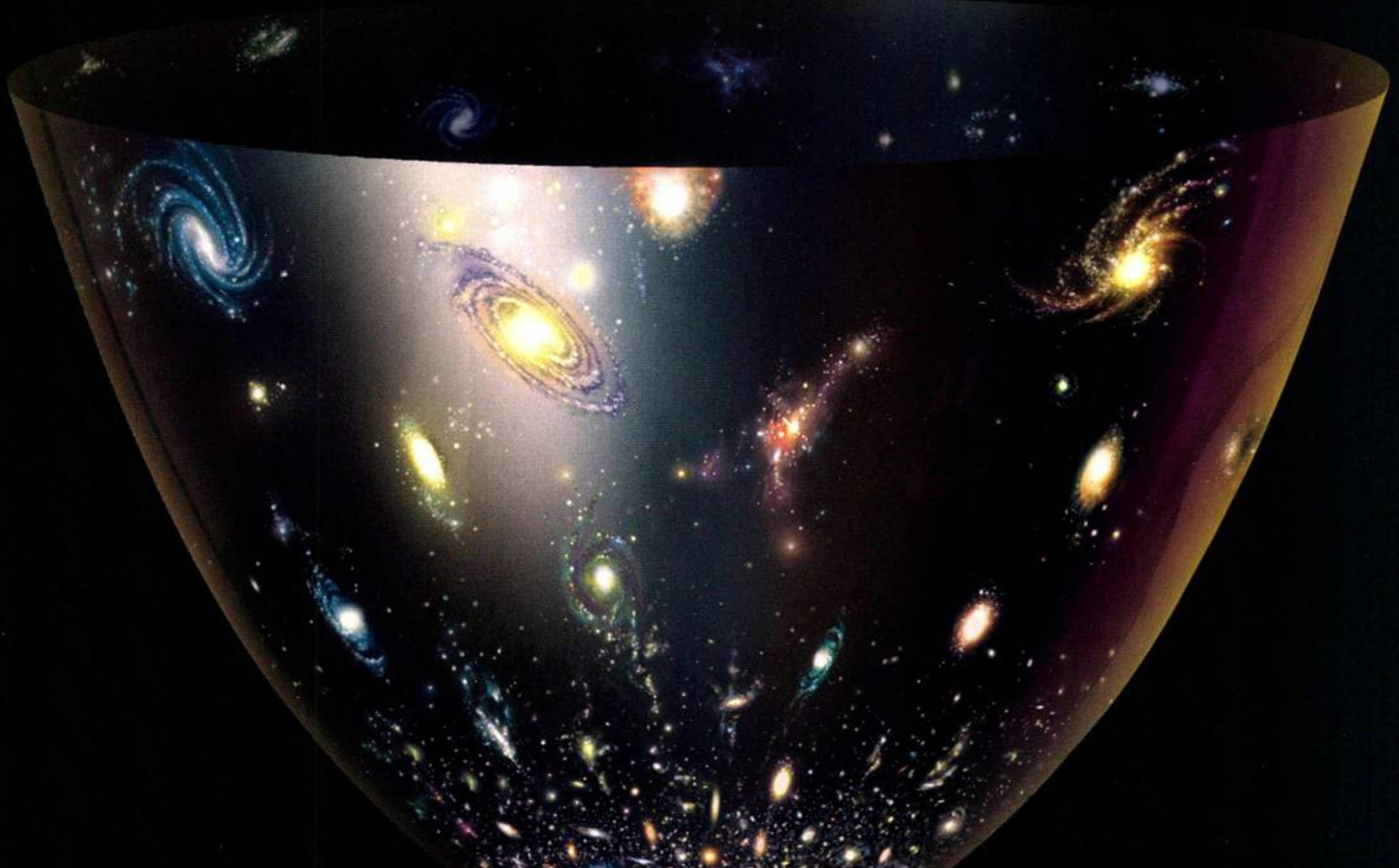
# Getting a grip on the universe

In their quest to understand the universe, astronomers are staking a claim on everything from atoms to superclusters of galaxies. /// BY HENDRIK SCHATZ, CHRIS LAWS, AND PAMELA L. GAY



**THE BIG BANG** gave birth to the universe roughly 14 billion years ago. In the first instants afterward, matter appeared, then stars and galaxies, and it all began to evolve into the universe we see today. As astronomers look deep into the cosmos — and far back in time — they find that creation is a single, connected story spanning large and small and linking the remotest past to the farthest future. *ASTRONOMY:* ROEN KELLY

Astronomy is a "big" science. It deals in big things, big distances, and big ideas. So it's a bit surprising to find astronomers exploring small things — *really* small things like subatomic particles — as they seek to write a history of the universe. Yet from the teeny space deep inside an atom to the vast chasms at the farthest reaches of the cosmos, astronomers need to understand it all if they're going to understand anything.

Astronomers do have one thing going for them: Everywhere they look in the cosmos, the rules appear the same. Three hard-won principles govern cosmology, astronomy's science of how the universe began and developed. First, the physics that works on Earth works the same way the universe over. Second, nothing about the place we occupy on Earth is unique or even special. And third, the universe is homogeneous and isotropic; in other words, the universe is similar everywhere and looks the same in every direction.

As yet, astronomers cannot fill in every detail. But they have assembled a broad understanding of how galaxies and planets and trees and cars and cats and people came to be. Similar to many human stories, cosmology tells of birth, growth, and death. It's a three-act play that ties together the creation of the elements, the formation of stars and planets, and the ultimate fate of the universe. You could call it the biggest story going.

## Act 1: Creating the elements /// BY HENDRIK SCHATZ

Big or not, cosmology begins in the realm of the incredibly small. Everything in the cosmos consists of atoms, and the core of an atom, its nucleus, is tiny. A hundred billion atomic nuclei piled on top of each other would stack up no thicker than this page.

Every atomic nucleus, except hydrogen, is built from positively charged particles (protons) and particles with no electric charge (neutrons). Hydrogen is the simplest atom: it has just a single proton. Surrounding every nucleus is a whirling cloud of electrons, lightweight particles with negative charges. Everything there is to see in the universe, from stars to people, is made from these three bits of matter. When joined together in various combinations, they form the chemical elements.

But where did the elements come from? The answer varies from one to the next, but all atoms ultimately arose from a single source: the immediate aftermath of the Big Bang.

### In the beginning

Following the Big Bang, the universe consisted of a primordial "soup" of energy. About one minute later, protons and neutrons condensed from this soup. Over the next few minutes, protons and neutrons fused, creating helium plus trace amounts of lithium and beryllium. Many protons remained unattached, becoming hydrogen nuclei.

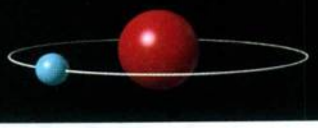
So far, so good, but four elements make a skimpy ingredient list for a universe. And that goes double because when you consider the minute quantities of lithium and beryllium, it's really just two elements. (These were so rare that astrophysicists lump them and all other elements heavier than helium into a catch-all category called "metals.")

**THE WISPY CRAB NEBULA** is an expanding debris cloud from a supernova that exploded in A.D. 1054. The cloud, rich in newly synthesized elements, will help make new stars. JAY GALLAGHER (U. WISCONSIN)/WIYN/NOAO/NSF

**THE ELECTRON** is the lowest-mass stable particle. Electrons moving in a conductor make electricity.
**MASS:** $9.9\text{x}10^{-31}$ kilograms
**SIZE:** $5.6\text{x}10^{-15}$ meters

**UP AND DOWN QUARKS** combine in threes to make protons and neutrons.
**MASS:** $6.4\text{x}10^{-28}$ kg
**SIZE:** n/a

**A PROTON** forms the heart of a hydrogen atom. Heavier elements have more protons.
**MASS:** $1.7\text{x}10^{-27}$ kg
**SIZE:** $1.7\text{x}10^{-15}$ m



**HYDROGEN**, the lightest element, is simply a proton and an electron *bound together.*
**MASS:** $1.7\text{x}10^{-27}$ kg
**SIZE:** $1\text{x}10^{-10}$ m

Making more elements took work, and whenever it can, nature opts for the easy way. With atomic nuclei, this means settling into the lowest energy state possible. As it happens, the atom with the lowest energy state is nickel. So why isn't the universe nickel-plated from end to end? The answer lies in nuclear physics.

Atoms grow when combinations of two or three nuclei slam together. One of nature's four fundamental forces, the strong nuclear force, governs how atoms combine and break apart. In an early universe filled almost totally with hydrogen and helium, the nuclear force had no easy way to fuse nuclei into heavier elements. For example, helium nuclei have two protons and two neutrons; a helium nucleus fusing with a proton (a hydrogen nucleus) would, altogether, add up to five nuclear particles. Fusing two helium nuclei would add up to eight nuclear particles. Both combinations are unstable, spontaneously breaking apart. Likewise, two protons were unable to stay together.

Thus the universe got stuck, unable to make substances much more complex than hydrogen and helium. (Those trace quantities of lithium and beryllium formed under special circumstances which guaranteed their rarity.)

But the universe getting stuck was a good thing for us because it led to our existence. Any gas clouds in a nickel-rich cosmos would have cooled rapidly and formed cold metallic blobs, neutron stars, or black holes — not a very friendly environment for life. In our primordial universe of hydrogen and helium, however, gas clouds made stars, some of which have shined for billions of years. Stars shine because they are finishing the job the Big Bang left undone. They are slowly releasing energy by fusing hydrogen and helium into heavier elements, ultimately forming — among many, many other things — lots of nickel.

## Stellar alchemy

Stars still faced a challenge making heavy elements. One form of beryllium has, for example, eight nuclear particles and is called beryllium-8; it's unstable and decays nearly instantly. The only way for it to form a heavier element is for beryllium-8 to capture a helium nucleus before decaying. Although this is an extremely unlikely situation, nuclear physics once again comes to the rescue.

When atoms collide, the result carries the combined energy of the two nuclei and their motion. If the total energy of that system — motions included — *exactly* equals the energy of a new atom, the transformation into a new element is straightforward. If there's too much energy from too much motion, however, the nuclei have to emit a particle in order to fuse, while if the energy is too low, the nuclei simply bounce apart.

The keys to making this work are both high temperatures inside a star and a huge number of available atoms. At about 100 million kelvins, a beryllium-8 nucleus can capture a helium nucleus in just the right way; their energy strikes a "resonance" that produces a carbon atom. And the trillions of atoms involved more than compensate for the very short amount of time ($10^{-16}$ second) before beryllium-8 decays. The result is lots of carbon gets made.

As far back as 1954, Cambridge University physicist Fred Hoyle predicted this resonance based on the abundance of carbon in nature. To test Hoyle's idea,

ASTRONOMY: ROEN KELLY

**THE TOP QUARK** was discovered at Fermi National Laboratory in 1995.

**MASS:** $3.1 \times 10^{-25}$ kg
**SIZE:** n/a

**URANIUM**, the heaviest naturally occurring element, fuels nuclear power plants and submarines.
**MASS:** $4.0 \times 10^{-25}$ kg
**SIZE:** $3.5 \times 10^{-10}$ m

**HUMAN DNA** encodes a unique pattern of information for every individual within a double helix pattern.
**MASS:** $1.0 \times 10^{-24}$ kg
**SIZE:** $2.0 \times 10^{-9}$ m

**A CELL** is the smallest independent living organism able to reproduce itself exactly.
**MASS:** varies by type
**SIZE:** varies by type

Willy Fowler and his colleagues at Caltech's Kellogg Radiation Lab set up an experiment to search for carbon resonance. In 1957, the group announced its discovery of conditions that produce beryllium-helium fusion. This removed a major roadblock in astronomers' understanding of how elements formed, and it netted Fowler a Nobel Prize in physics.

Fowler's pioneering discovery showed that most elements — from hydrogen up through nickel — are created in the bellies of stars. Stars begin by fusing hydrogen into helium and then, over millions or billions of years, they fuse heavier and heavier nuclei. The resulting elements are thrust into space by booming stellar winds or when a star explodes as a supernova, contaminating the galaxy with all those "metals." Ultimately, this process made the solar system, complete with iron, carbon, oxygen, and other constituents of life. But other elements — those heavier than nickel — have far different origins.

## Heavy metal

To form heavy metals inside stars, another process besides garden-variety fusion takes place. Called the s-process (for slow process), the technique works when seed nuclei, typically iron, are struck by neutrons. Neutrons have an advantage in this kind of encounter. Because they carry no electric charge, neutrons are immune to the electric repulsion that protons feel when colliding with a nucleus. So an atomic nucleus bombarded with neutrons will eventually capture some and grow heavier. The nucleus soon becomes unstable and decays, converting one neutron into a proton and releasing a negatively charged particle (an electron) and a tiny uncharged particle (a neutrino). This adds a proton to the nucleus, which transforms it into a new element.

Yet it's not quite that cut-and-dried. Unlike protons (hydrogen nuclei), which are ubiquitous, neutrons are not as readily available in large numbers. Unattached neutrons decay into ordinary protons in about 10 minutes. Stars that formed from the debris of past supernovae, however, emit a stream of neutrons, and any nuclei in their path will capture one of them about once every year.

The slow process certainly lives up to its name, yet despite the leisurely pace, quite a few neutrons accumulate over a billion years in a galaxy full of stars. The s-process ultimately accounts for about half the heavy metals up to lead.

## Going to extremes

Besides stars and the s-process, the nuclei of the remaining heavy elements come from the poorly understood r-process (for rapid process). The r-process has atomic nuclei capturing neutrons in fractions of milliseconds, which requires staggering numbers of neutrons hanging around awaiting capture. Astronomers calculate the r-process needs at least a pound of neutrons in a sugar-cube-size volume of space, plus a temperature of several billion degrees to work.

---

**Hendrik Schatz** *is an assistant professor at the National Superconducting Cyclotron Laboratory at Michigan State University in East Lansing.* **Chris Laws** *is an astronomer at the University of Washington in Seattle.* **Pamela L. Gay** *can be found either reducing data or "virtually" teaching at Swinburne Astronomy Online.*

**DUST AND GAS MINGLE** in thick clouds such as the Trifid Nebula. Shock waves from bright, newborn stars surge through the cloud, driving lumps of dusty gas into making more stars. GEMINI OBSERVATORY

**HUMAN BEINGS** were the first life-form on Earth to reach for the stars.

**MASS:** 90 kg
**SIZE:** 2 m

**ASTEROIDS** are the smallest rocky and metal-rich objects in the solar system.
**MASS:** 8.7x10$^{20}$ kg
**SIZE:** 9.5x10$^{5}$ m

**PLUTO** is the largest known icy body in the outer solar system. Some argue it's not really a planet.
**MASS:** 1.3x10$^{22}$ kg
**SIZE:** 2.4x10$^{6}$ m

**MARS** is a terrestrial planet whose early history may have paralleled Earth's — *perhaps including life.*
**MASS:** 6.4x10$^{23}$ kg
**SIZE:** 6.8x10$^{6}$ m

Where would so many free neutrons come from? Many astronomers think neutron stars provide the answer. However, these stars are compact: a neutron star crunches the mass of the Sun into the size of a small city. Not only is a neutron star exceedingly dense — a tablespoonful would outweigh 4,000 aircraft carriers — but its extraordinarily powerful gravity binds its material tightly to the star.

But *colliding* neutron stars might free up a vast supply of neutrons. Such mergers would take place at extremely high velocities, creating titanic explosions that would release loads of neutron-rich material. Supernova explosions that form neutron stars might be another source. In each of these scenarios, the conditions ripe for the r-process could exist for a few seconds.

Could half the heavy elements in nature have been created in one second here and one second there? Astronomers can't say because they don't know the precise rate at which neutrons decay.

At bottom, the r-process still defies explanation, although astronomers hope to solve the puzzle relatively soon. Recent observations have uncovered numerous stars in the Milky Way's halo that provide a window into the r-process. These stars formed a long time ago from nearly pristine gas left by the Big Bang and then were polluted by a single r-process event some 13 billion years ago. The patterns of elements that astronomers observe in these stars' spectra may provide some clues into how the process works.

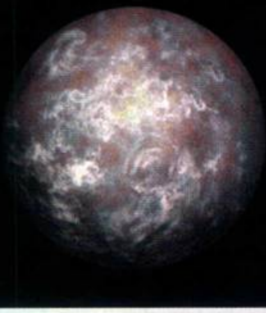
As astronomers are looking skyward for answers, physicists developing ground-based tests are on the verge of recreating the r-process in the lab. New, powerful accelerators — like Michigan State University's National Superconducting Cyclotron Laboratory — are gearing up for numerous experiments. Next-generation testbeds such as the proposed Rare Isotope Accelerator or an upgrade of Germany's GSI Accelerator are now on the horizon. Together with computer simulations, these tests offer real hope of understanding how heavy elements formed in the universe.

## Act 2: Making stars and planets /// BY CHRIS LAWS

On the scale of the very small, the universe seems to work just fine. Our bodies are packed with protons, neutrons, and electrons, and their interactions keep us alive. But what about the pretty objects we see in the universe — stars, planets, nebulae, galaxies? These things exist on a completely different and larger scale.

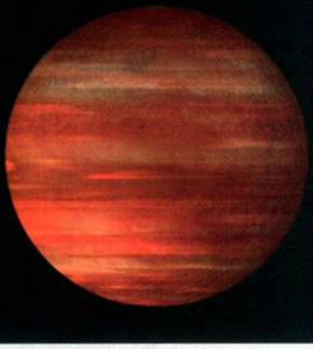
Such objects not only dominate our naked-eye view of the heavens, they also occupy intellectually accessible territory. Human minds have experience with the size of a planet, and we can imagine the immensity of Jupiter-size brethren in other systems. We begin to grasp the size of a star by recognizing that the largest stars rival the size of Earth's orbit, and the smallest are similar in circumference to the size of cities or islands.

**EARTH'S SIZE** lets it remain tectonically active, and its position in the solar system keeps it habitable.
**MASS:** $6.0\times10^{24}$ kg
**SIZE:** $1.3\times10^{7}$ m



**3 TO 5 EARTH MASSES** is about the largest terrestrial planet that can form. Larger ones are gas giants.
**MASS:** $3.0\times10^{25}$ kg
**SIZE:** $2.2\times10^{7}$ m

**JUPITER** is our solar system's largest planet, and it is the standard used for weighing other worlds.
**MASS:** $1.9\times10^{27}$ kg
**SIZE:** $1.4\times10^{8}$ m



**13 JUPITER MASSES** is the upper limit for a planet. Above this size, nuclear reactions create stars.
**MASS:** $2.5\times10^{28}$ kg
**SIZE:** $1.4\times10^{8}$ m

Stars mark a starting point not just in comprehending the size of celestial objects, but also in understanding their physics. Stars don't grow haphazardly. How a star evolves depends solely on its mass. Because mass determines the initial pressure and, therefore, the temperature within the star's core, the mass of a star governs a set of nuclear fusion reactions. These in turn control how large stars can grow, and how small they can be and still be called stars. Understanding stellar evolution, therefore, is the key to understanding cosmic evolution.

## The matter of mass

A normal star walks a tightrope. Its stability depends on balancing a tendency to collapse under the pull of gravity with a push to expand from the force of its own radiation. Gravity strives to compress a star to an ever-greater density, which produces a higher temperature and a larger outflow of energy. Radiation pushes back the collapsing gas, resisting gravity. So long as neither force can overpower the other, a balance results.

A star's mass and the way it generates energy determine where this balance will lie at any given time during a star's life. A massive star fusing hydrogen in its core is exceedingly hot and emits lots of radiation. Such stars, as a result, have much larger diameters than low-mass stars, which find their balance points at cooler temperatures and smaller diameters.

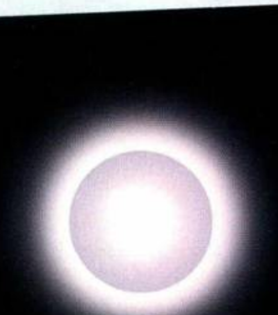
Many older, evolved stars also have significantly larger diameters than ordinary stars of either high or low mass. Such an older star generates energy by fusing the helium in its core, produced during the star's early life. This simple change in nuclear reactions greatly alters the balance between gravity and radiation. Helium fusion happens at a much higher temperature, so the star expands. During this phase of its life, a star ten times the mass of the Sun swells to a size thousands of times greater. A giant like this, placed at the Sun's location, would easily engulf Mercury, Venus, and Earth.

## Peeling the onion

As a massive star evolves, nuclear fusion reactions in its core run at increasingly greater temperatures and pressures. This creates "onion layers" inside the star with progressively heavier elements lying deeper inside. The most massive stars end their lives spectacularly, exploding as supernovae and leaving behind neutron stars and black holes. Lower-mass stars like the Sun have a gentler fate. They lack the internal pressure needed to create the heaviest elements. Instead, they shed their outer atmospheres, rich in synthesized elements, forming planetary nebulae. At the same time their cores collapse. The end for them is becoming a white dwarf — essentially, the exposed remnant core of the original star.

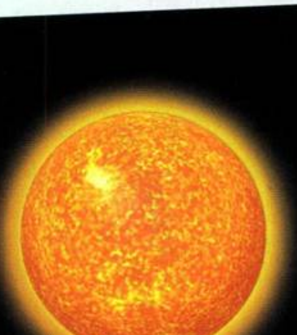
Also playing a role in determining a star's size is its composition. The first stars in the universe contained virtually nothing heavier than helium — in other

**GLOBULAR CLUSTERS,** such as M13, are as ancient as the galaxies they accompany. Lacking materials for making new stars, their futures are dim. CANADA-FRANCE-HAWAII TELESCOPE/COELUM/JEAN-CHARLES CUILLANDRE



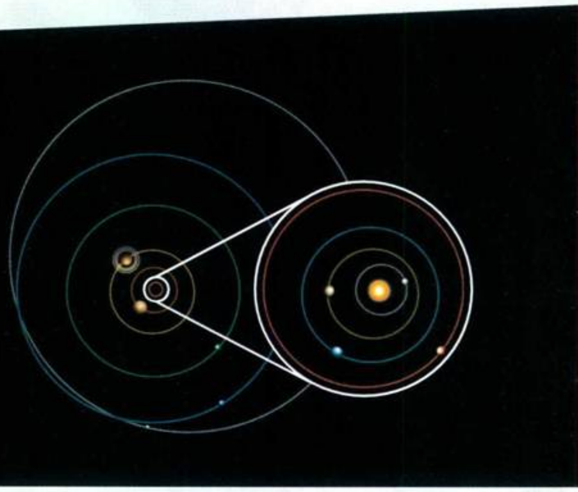
**WHITE DWARFS** are the leftover cores of dead stars that expelled their atmospheres.

**MASS:** $2.0\times10^{30}$ kg
**SIZE:** $3.5\times10^{7}$ m



**THE SUN** is a completely normal star in an average part of the galaxy.

**MASS:** $2.0\times10^{30}$ kg
**SIZE:** $1.4\times10^{9}$ m



**THE SOLAR SYSTEM** consists of nine planets plus loads of asteroids, comets, and icy objects.

**MASS:** $2.0\times10^{30}$ kg
**SIZE:** $1.5\times10^{14}$ m

words, no metals. Because they have more complex nuclear structures, metals absorb and radiate energy in more ways than simple hydrogen and helium atoms can. This means gas clouds lacking metals — clouds of pure hydrogen and helium — can't cool effectively as they contract and create stars. These first stars loomed hotter and larger than the stars of today. Additionally, stars forming from gas clouds rich in metals develop atmospheres laden with heavy, radiation-absorbing atoms. This makes it hard for light to escape the outermost layers of the star's atmosphere. These opaque regions also push out their girth.

Stellar evolution aside, metal-rich stars have another attraction for astronomers. Both planets (and people) are built from metals, so that's where astronomers look when they want to hunt for extrasolar planetary systems.

## Planetary systems

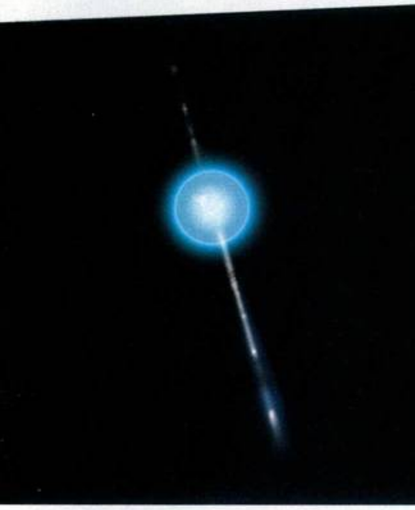
The discovery of the first exoplanet was announced in 1992, and by now, astronomers have identified more than a hundred stars with at least one planet orbiting them.

Two points worth noting have emerged from the searches. First, a star-forming cloud that's all hydrogen and helium doesn't have much chance of making a planetary system. Second, a star's physical size affects the likelihood of its hosting a planetary system.

Intuitively, you might think massive stars would spawn massive planets, and there does appear to be some truth to this. Stars less massive than the Sun seem less likely to have massive planets in orbit. Yet the jury is still out because scientists have searched too few stars as yet.

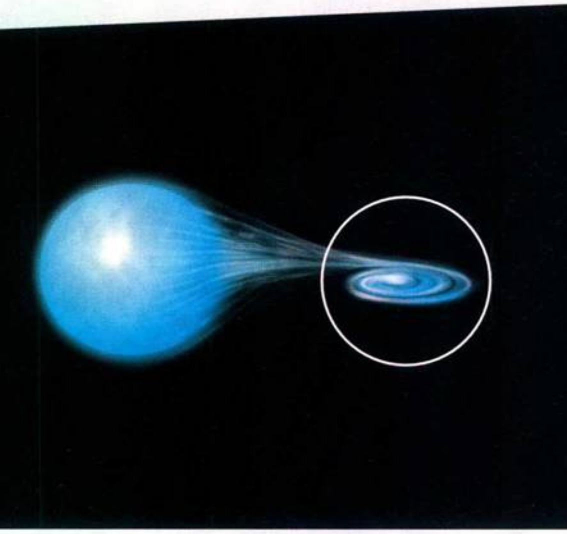
While astronomers are interested in all kinds of exoplanets, they're especially keen on finding potentially habitable ones — other Earths. This means finding a planet orbiting in a star's habitable zone. This is the region where a planet could support liquid water. The zone's width and location depend on the star's luminosity and size. Bright, large stars are hotter than average stars; they have wider zones where habitable planets could exist. On the other hand, a potentially life-supporting world orbiting a lightweight star would have to lie very close to the star to remain warm enough.

The outer limit for a star's habitability zone varies greatly from one star to the next. It might range from 10 million miles for a small, cool star to as far as a billion miles in the case of a large, hot one. With the Sun, the habitable zone ranges just inside Earth's orbit to roughly that of Mars's, or from 89 to 128 million miles (143 to 206 million kilometers).

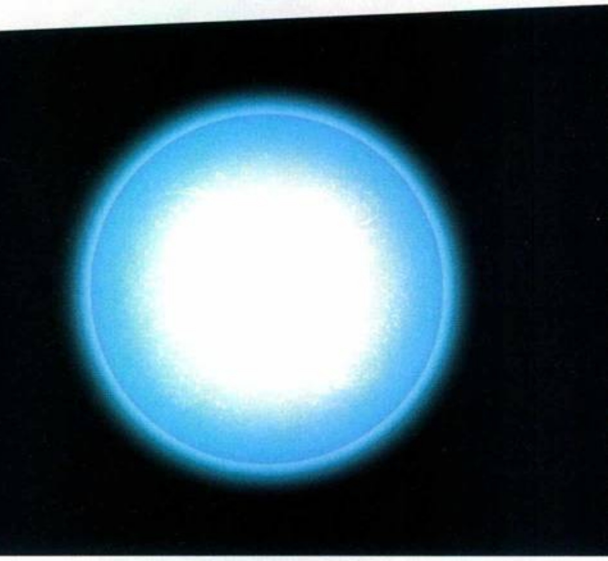


**NEUTRON STARS** are compressed by gravity until electrons and protons merge into neutrons.

**MASS:** $2.8 \times 10^{30}$ kg
**SIZE:** $1.5 \times 10^{4}$ m



**STELLAR MASS BLACK HOLES** can form when gas, stripped from one star, falls onto another, increasing its mass to become a black hole.
**MASS:** $1.0 \times 10^{31}$ kg
**SIZE:** $3 \times 10^{3}$ m



**7 TO 25 SOLAR-MASS STARS** will form neutron stars when they die in supernova explosions.

**MASS:** $3.0 \times 10^{31}$ kg
**SIZE:** $8.1 \times 10^{9}$ m

In all probability, lots of planets exist in our galaxy and others. But to form planets, the cosmos needed to produce more than one generation of stars. Chasing down the locations of stars that are metal-rich and second-generation (or later) leads astronomers into the realm of the galaxies. These gigantic structures, weaving together stars and the raw materials for making them, are the basic pieces of the visible universe, much as protons and neutrons are the building blocks of atomic nuclei.

## Act 3: Here come the galaxies /// BY PAMELA L. GAY

The first stars lived, made heavy elements, and died. But for a first-generation star to pass on its heavy elements to later stars, it wasn't enough simply to spew the elements into space. Early stars had to fling their heavy elements into just the right places to hand them down to subsequent stellar generations.

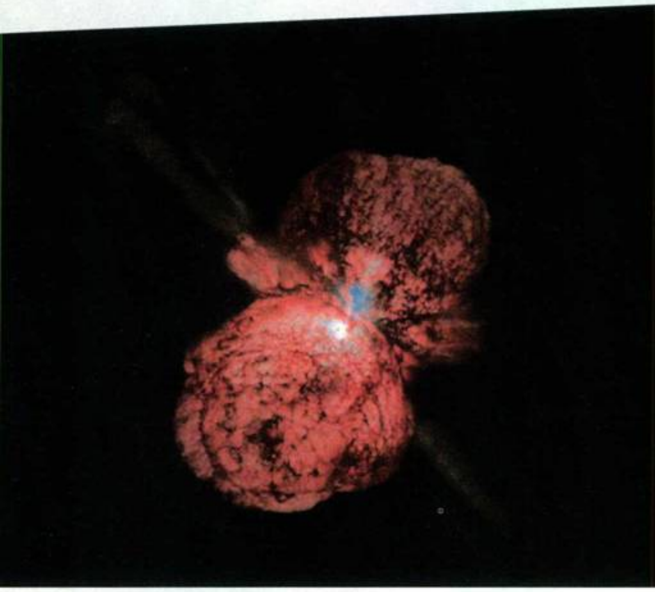
The richly populated disk of the Milky Way, for example, is a great place for stars to pass on their legacy. The disks of spiral galaxies like ours are prime breeding grounds for metal-rich stars, and they can operate for many stellar generations. To follow these elements as they journey from one generation to the next, astronomers delve into how galaxies like the Milky Way form and evolve.

### Bright start

In the beginning, all was hydrogen and helium. One clump of hydrogen ignited, and the first star was born. Then another star lit up, and another, and the universe glowed with their light. Stars lacking metals shine brighter than their metal-rich descendants, so these first stars blazed brilliantly. Only a few million years after the Big Bang, the most massive among them exploded as supernovae, scattering their newly created elements into the early cosmos.

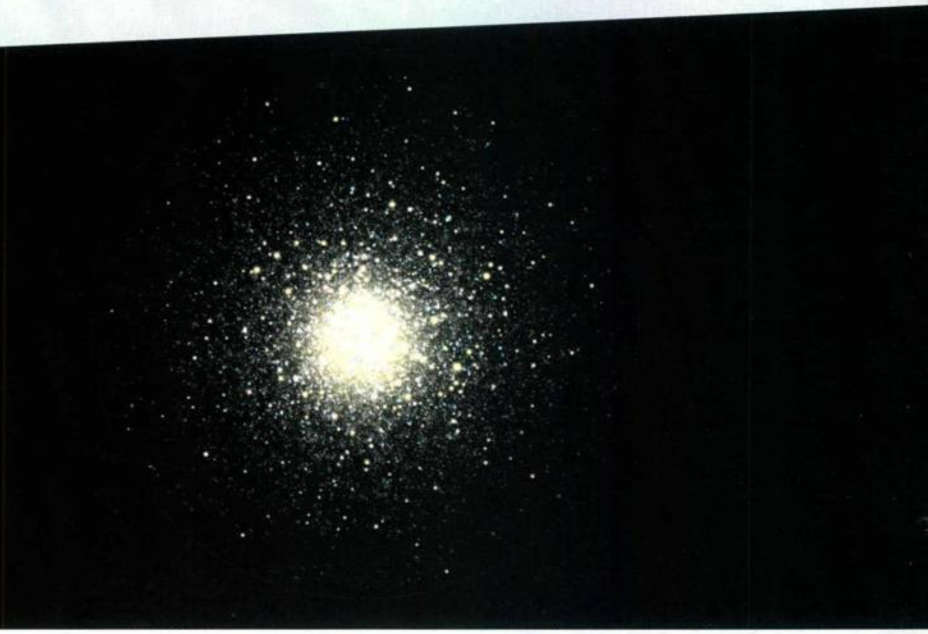
The first galaxies formed around the same time the first stars ignited, and each galaxy provided a new location for star formation. Galactic size was important in spawning further generations of stars. Galaxies in the present-day sky bear this out. The Ursa Minor and Draco dwarf galaxies aren't much larger than fat globular star clusters. These dwarf galaxies contain old stars, and they seem to have stopped making new ones ages ago. Astronomers are not clear on what happened, but one idea is that the first generation of stars (and possibly the second) in these dwarf systems became supernovae. The force of many powerful

**SPIRAL GALAXIES** are the star-making factories of the universe. Vast amounts of gas and dust fill their many-armed disks, which are outlined by hot young stars and clouds of dust. GEMINI OBSERVATORY



**STARS LARGER THAN 25 SOLAR MASSES** collapse into black holes after exploding as supernovae.

**MASS:** $5\times10^{31}$ kg
**SIZE:** $1.2\times10^{10}$ m



**GLOBULAR CLUSTERS** were among the first structures to form, and therefore they contain metal-poor stars.

**MASS:** $6.0\times10^{35}$ kg
**SIZE:** $3.4\times10^{17}$ m

explosions blew all the gas in the galaxy away, effectively shutting down star-making in these small galactic bodies.

## No metals, no Earths

Small galaxies may have trouble retaining materials for new stars, but big galaxies have no difficulties whatever. A glance around the Milky Way shows abundant star formation going on — even backyard telescopes show this in places like the Orion Nebula and the Eagle Nebula. Wherever large, hot stars are shining, star formation is taking place.

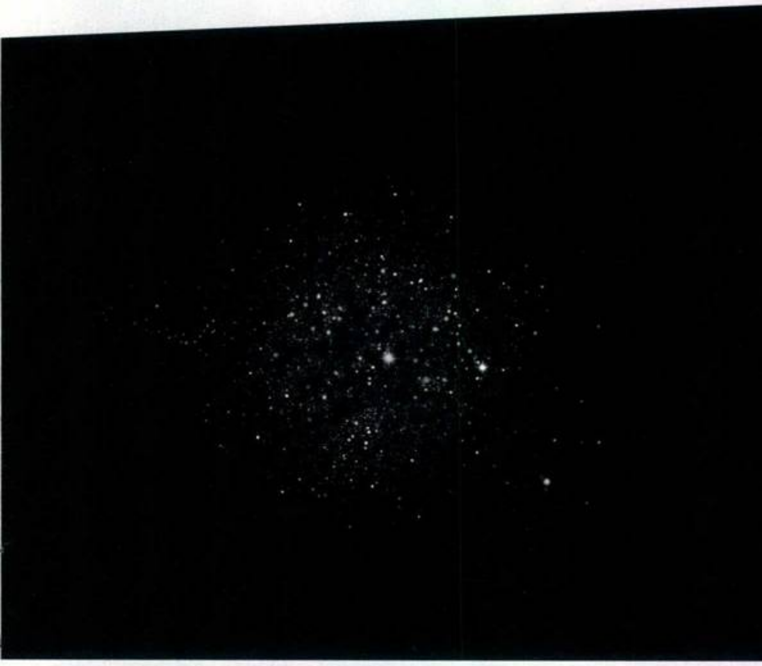
Massive stars burn hot, live fast, and die young. Existing for only a few million years, these behemoths fuse elements up to iron in their cores before exploding. Smaller stars, by contrast, are conservative — expending their stockpiles of nuclear fuel slowly and lasting for billions of years.

As the Milky Way formed, its first stars formed from gas in what is now the galaxy's far-flung halo. Stars still reside there, but the majority are extremely metal-poor. As first-generation stars died, the mass they expelled left the halo and fell toward the emerging disk of the Milky Way, where it gradually blended with the disk's gas and dust. This made the galactic disk, rather than the galactic halo, a far richer environment for planet production, especially those planets that could support life.

## Reformation and change

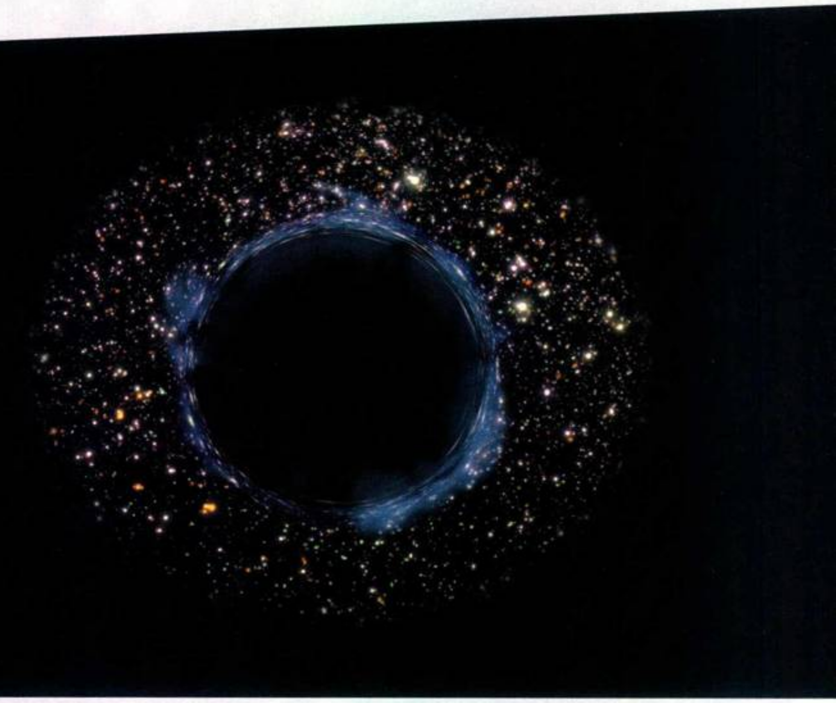
Through the ages, the Milky Way has plugged along forming stars that synthesize metals and then shaping this material into new stars and the occasional planet. Left alone, it would probably continue its current activity until it used up all the available gas and dust. Unfortunately, the universe will not let things be.

In a few billion years, the Milky Way and its near neighbor, the Andromeda Galaxy, will begin a dance of death as they spiral together and merge. However catastrophic, galaxy collisions and mergers are a normal part of the universe's evolution. At this very moment, the Milky Way is shredding at least one dwarf spheroidal galaxy, the Sagittarius Dwarf. It will also consume the Large and Small Magellanic Clouds, and all the other neighboring galaxies, large and small. Each collision — and especially the big one between the Milky Way and



**DWARF GALAXIES** are among the most numerous galaxies in the universe. Some are still forming.

**MASS:** $2.0\text{x}10^{36}$ kg
**SIZE:** $9.3\text{x}10^{19}$ m



**SUPERMASSIVE BLACK HOLES** power quasars and lurk (often quietly) in the centers of most large galaxies.

**MASS:** $2.0\text{x}10^{39}$ kg
**SIZE:** $6.0\text{x}10^{12}$ m

Andromeda — will spark frenzied, new rounds of star creation for as long as the raw materials hold out.

When large spiral galaxies collide, gas and dust in their disks will stream toward the galaxies' centers, and central black holes, usually dormant, will reawaken. The activity will kick star formation into high gear. As the collision progresses, the dust and gas that's not converted into stars or eaten by the black holes is driven off into intergalactic space. Eventually, the galaxies may merge and create a gas-poor, giant elliptical system that's devoid of new stars.

## Harassing a galaxy to death

The largest irregularities in the early universe gave rise to the giant galaxy clusters and superclusters that occupy our modern universe. Within these crowded groups of galaxies, the star-making process suffers what astronomers term "galaxy harassment."

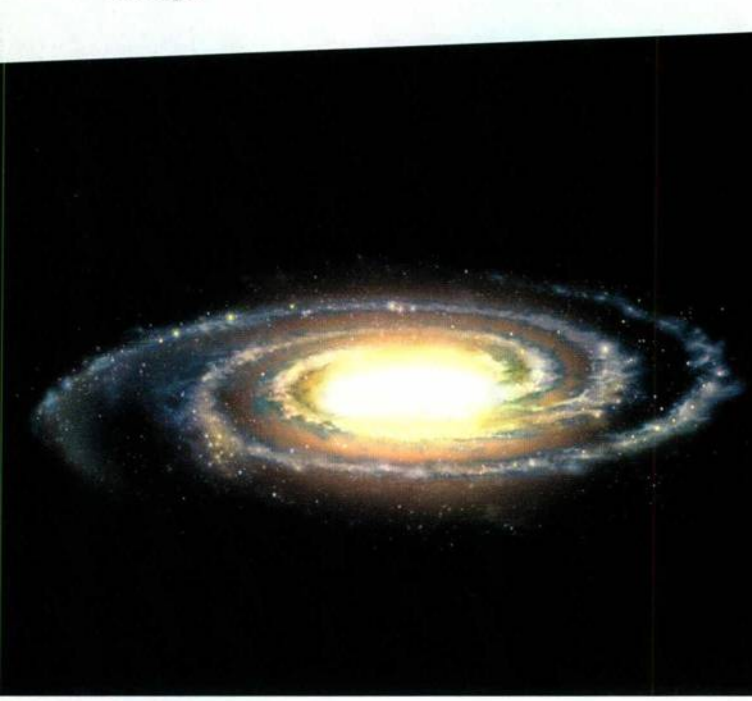
As galaxies gravitationally interact, they strip away gas from each other. After multiple interactions (or one very large interaction), a once thriving spiral galaxy will find itself bled of materials for making more stars, and it will even have lost its shape.

Given enough time, all the gas in a galaxy will either create stars or be stripped into the vast intergalactic wastelands where stars don't generally form. As star formation ends in a galaxy, no new metals will be created. The galaxy's old stars will slowly die, leaving behind white dwarfs, neutron stars, and black holes. These stellar remnants will gradually cool and grow dimmer.

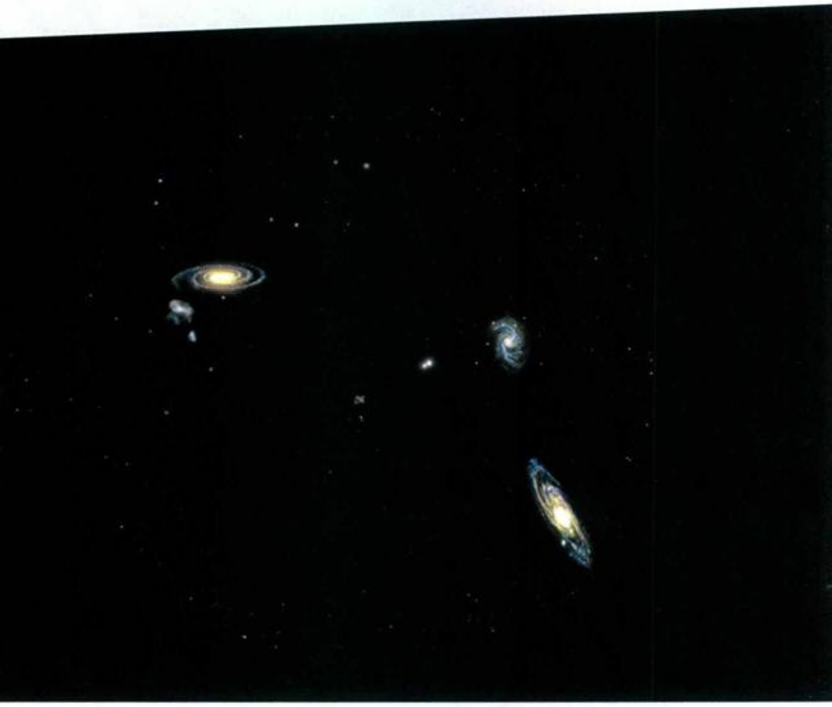
The end of star formation does not end the cosmic evolution scenario, however. Gravity continues to draw systems together. Galaxies merge. Groups of galaxies merge into clusters. Clusters merge to form superclusters. These, in turn, trace the walls and voids of the cosmic superstructure. Like Swiss cheese with expanding air holes, the spaces in the universe grow and the walls will get thinner as the entire universe expands.

In determining how the large-scale structure of the universe is likely to evolve, cosmologists have looked back to the initial irregularities that formed the first stars, the first galaxies, and even the first galaxy clusters. Locked in the distribution of those irregularities is information about the expansion of the early universe. From that information, cos-

**GALAXIES NATURALLY GATHER** into groups, clusters, and superclusters. As time passes, galaxies will collide and merge, using up the available gas and eventually shutting down star formation. GEMINI OBSERVATORY



**THE MILKY WAY GALAXY** is an average spiral galaxy in a typical galaxy group. It contains between 200 and 400 billion stars
**MASS:** $1.4\times10^{42}$ kg
**SIZE:** $7.4\times10^{20}$ m



**THE LOCAL GROUP** contains three large spirals (the Milky Way, Andromeda, and the Pinwheel Galaxy) plus numerous dwarf and irregular galaxies.
**MASS:** $4.6\times10^{42}$ kg
**SIZE:** $7.3\times10^{22}$ m

mologists have determined that our universe is expanding and accelerating. One day, the voids between clusters will dominate every map of the cosmos, as galaxies and galaxy clusters become isolated bits of flotsam in a vast sea of nothing.

Some physicists predict that in the farthest future, matter itself may evolve. Seemingly stable particles may spontaneously break down, and black holes may evaporate as quantum effects shrink their mass, particle by particle.

## Descent into darkness

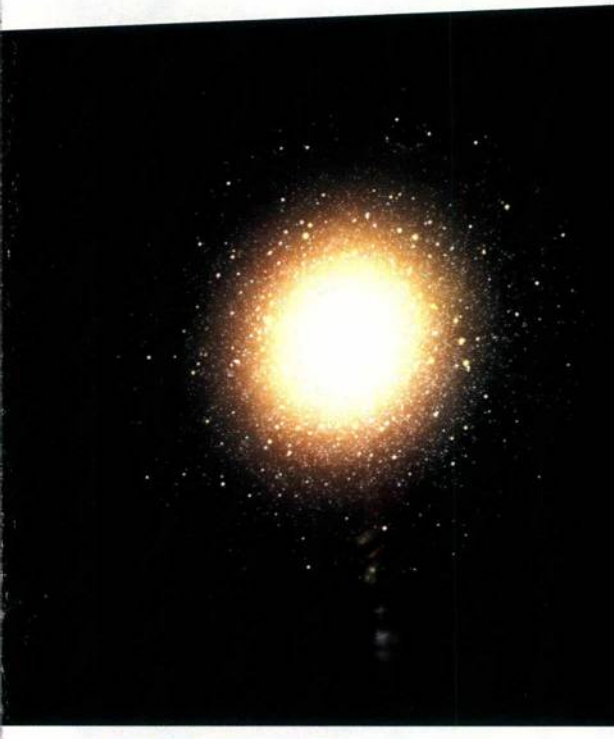
The goal of cosmology is a theory that ties together all of physics and allows us to understand the details of our universe's past, present, and future. That theory isn't here yet, but astronomers do have the understanding necessary to define our place in space.

From the Big Bang came hydrogen, helium, plus traces of lithium and beryllium. Stars created all other materials through their lives and in their deaths. In cases where the gravity of a galaxy hung onto its gas, the interstellar material became enriched to the point that planets formed around the newborn stars.

Through their generations, stars live and die in galaxies — at least as long as a galaxy retains gas. Supernova explosions in small galaxies, collisions between larger galaxies, galaxy harassment, and interactions with intracluster dust all work to shut down star formation. Over time, small structures combine into larger systems as galaxies merge into larger galaxies, and galaxy clusters gain members and merge with other clusters.

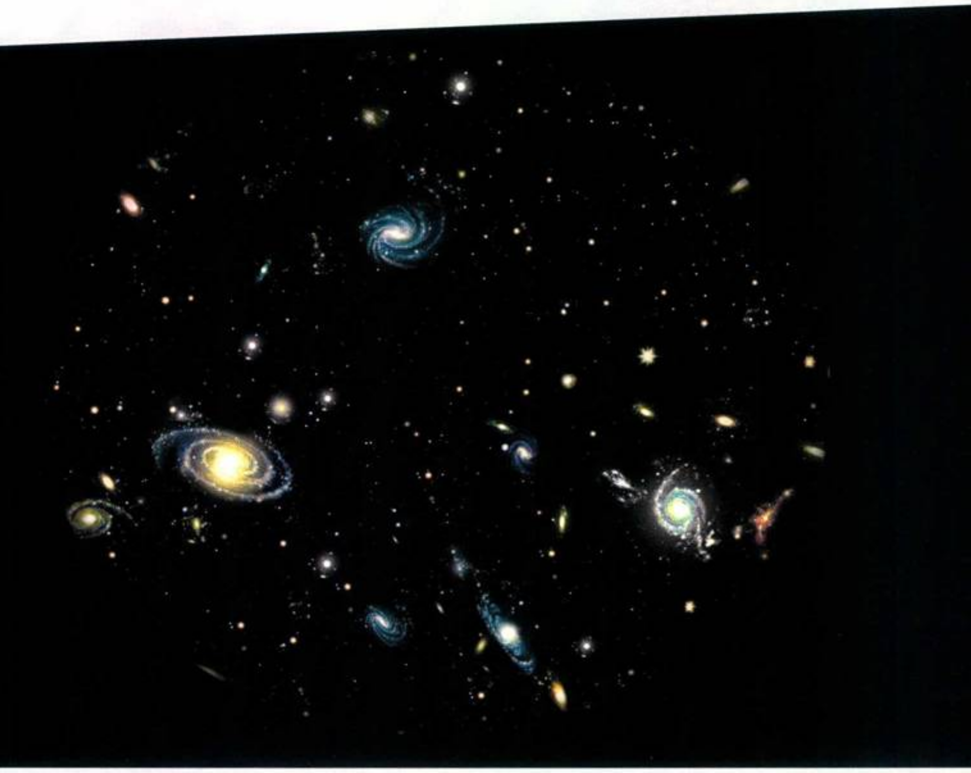
As star formation ends, while the universe continues to expand, the cosmos will sink into obscurity. From ashes to ashes and dust to dust, everything that formed from that first generation of stars will cool off and darken.

The big picture is a sad one. When the day comes that star formation ceases in the last galaxies, the universe will begin to end. Everything that sparked with life will die, and the universe that's known to us — and any other life-forms it contains — will draw to a close.



**GIANT ELLIPTICAL GALAXIES** form via the merger of two (and generally more) other galaxies.

**MASS:** $2.0\times10^{44}$ kg
**SIZE:** $1.3\times10^{22}$ m



**THE COMA-VIRGO CLUSTER** is just one of many galaxy clusters that trace the structure of the universe.

**MASS:** $4.0\times10^{45}$ kg
**SIZE:** $2.4\times10^{23}$ m

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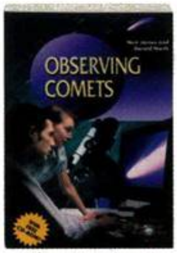
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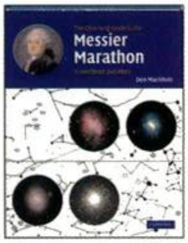
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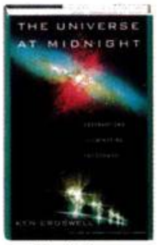
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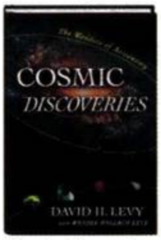
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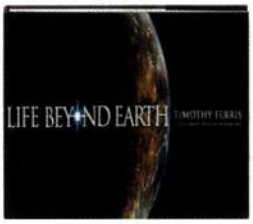
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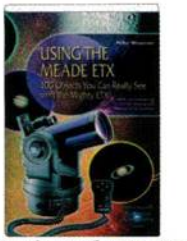
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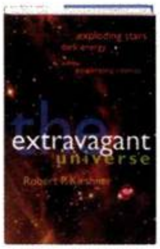
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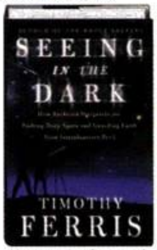
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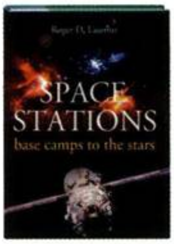
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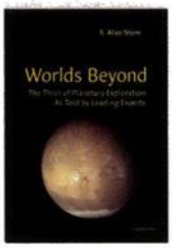
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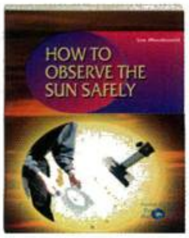
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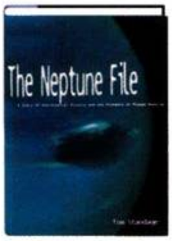
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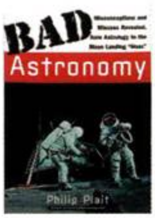
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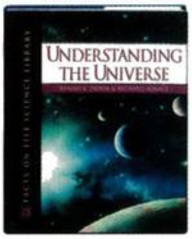
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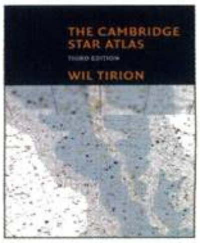
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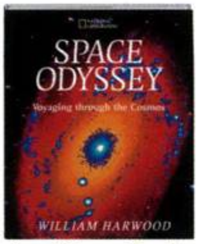
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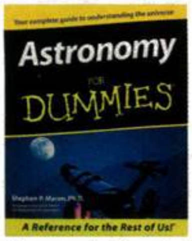
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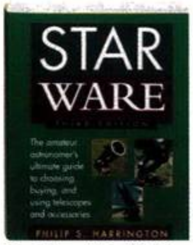
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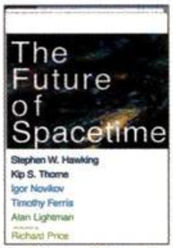
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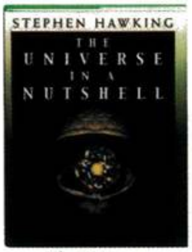
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Explore the Universe Annual September 2003 44/Z466/SS138

# Journeys into the new mil

The next decade promises to be a new golden age in solar system exploration. /// BY JOHN SHIBLEY

With the planned demise of the Galileo spacecraft in September 2003, planetary missions entered a temporary lull. Fortunately, it won't last long. Scientists have a multitude of spacecraft heading to Mars to augment the two orbiters already there. The Cassini spacecraft stands poised to revolutionize our understanding of Saturn, its rings, and its moons. And best of all, these missions represent the tip of the iceberg — in the next ten years, more than two dozen spacecraft will ply the solar system, from Mercury to Pluto and beyond.

## Full press on Mars

Wheels return to Mars in 2004 with NASA's Mars Exploration Rovers (MER). After the dismal failure of Mars Polar Lander in 1999, NASA returned to a technology endorsed by the success of 1997's Mars Pathfinder mission. Like Pathfinder, the twin 2004 spacecraft will plunge directly into the martian atmosphere from interplanetary space and bounce to a standstill on a cushion of air bags. The rovers contained inside are beefier variants, fully three times the size of Pathfinder's Sojourner rover. Whereas Sojourner roamed only a few dozen yards from its lander during a 90-day mission, the Mars Exploration Rovers will range up to 300 yards each day for at least three months. Each rover is loaded with scientific instruments and is completely autonomous from the lander that delivers it to the surface. Neither of the three-petaled base landers carries science experiments; everything needed for a successful mission is fitted to the rovers.

One signature feature of Pathfinder's lander, a mast topped with a twin-eyed camera, is fitted to the rovers this time around. Like Pathfinder's, these camera masts stand roughly the height of a person, but their stereographic cameras perform three times better than those flown on Pathfinder.

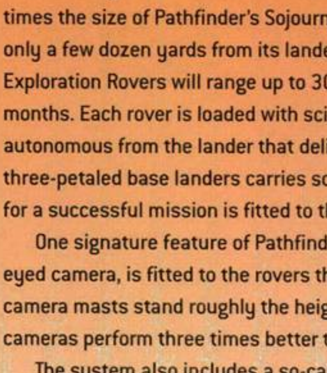
The system also includes a so-called thermal emission spectrometer, or TES. Like the TES presently flying in orbit aboard the 2001 Mars Odyssey spacecraft, the MER instrument will take pictures of heat radiating from rocks and soil. Scientists will use the images not only to discern types and amounts of certain minerals but also to determine whether water played a role in creating or shaping them.

Mars Pathfinder's rover sported a deployable snout that "sniffed" rocks. The 2004 rovers take this concept one step further. Each rover has a hinged boom with not one, but two types of spectrometers that bombard rocks with radioactive particles. Different minerals and their elements reflect the particles back to detectors at different strengths and signatures. Each boom also comes fitted with a tool that grinds through a rock's weathered veneer to catch a glimpse of what, quite literally, is inside. A microscopic imager, analogous to a geologist's loupe, will resolve exposed rock and soil down to fractions of an inch.

Both rovers, launched from Earth in late spring 2003, will close in on Mars during the first month of 2004. MER-1 punches into Mars's atmosphere for a landing on January 4, 2004, with MER-2 following soon thereafter in late January. Each performs engineering checks and stationary photo-reconnaissance of its landing site for four days before rolling off the landing pad to begin a 90-day mission.

Like Sojourner, the 2004 rovers are solar-powered. Mission length essentially hinges on the life span of rechargeable batteries. They not only provide electricity for science and rover systems, but also power heaters that keep sensitive parts of the landers' electronics warm during bone-chilling martian nights. The solar panels will provide current less efficiently as the Sun's angle lowers and as autumn and winter approach the rovers' landing sites.

This year also sees a European invasion of Mars. The European Space Agency (ESA) launched Mars Express from Russia during the summer of 2003. It enters Mars orbit on December 26, 2003, five days after ejecting a soft lander named Beagle 2, which reaches the surface of Mars on December 26. Mission planners expect Mars Express to carry out its mission for one Mars year (nearly two Earth years). Over that time, it



**MARTIAN SURFACE FEATURES** have been carved by water, wind, volcanoes, and, like this section of Hellas Planitia, some still-puzzling processes. Future orbiters with higher-resolution cameras may help solve these mysteries. NASA/JPL/MSSS

**A MARS EXPLORATION ROVER,** set to land in early 2004, wends its way across the rocky martian surface. Its sophisticated suite of instruments will analyze minerals and take images — from panoramic to microscopic. NASA/JPL

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will photograph the entire planet down to a resolution of 30 feet and, in some places, better than 12 feet. Mars's atmosphere — specifically the distribution of water vapor and ozone —and its circulation come under the direct scrutiny of two onboard instruments. Perhaps the most intriguing Mars Express experiment uses radar to prospect for subsurface water in the upper one to two miles of martian crust. It also will reveal the planet's subsurface rock structure.

Meanwhile, after landing on a cushion of air bags, Beagle 2 will swing out an articulated arm loaded with cameras, mineral-detecting spectrometers, a rock grinder, and a "mole" that can burrow up to 4 feet below ground for soil samples. The arm's microcamera will discern detail down to four-thousandths of a millimeter. Seeking evidence of life, long dead or still living, the mole's coring tool will collect samples for a gas analysis lab in the lander's body. The lander also comes with a weather station to measure air pressure, temperature, wind speed, and wind direction. It will take density and pressure readings in Mars's upper atmosphere during Beagle 2's descent.

Rounding out 2004's armada to Mars is Japan's Nozomi. This spacecraft would do a cat proud with its nine lives. Launched in the summer of 1998, it was designed to use gravity assists from Earth and the Moon to arrive at Mars in October 1999.

Its 1998 Earth encounter didn't deliver enough velocity, however; correction burns consumed too much onboard fuel, and problems soon snowballed. Japanese engineers bounced back by devising two more Earth flybys, in 2002 and 2003, that would kick the craft out to Mars. A solar flare fried its attitude-control electronics shortly after the 2002 flyby, resulting in an incorrect orientation in space that froze onboard fuel. Engineers recovered orientation, and now they hope enough fuel will thaw in time for Nozomi's engine to edge the craft into Mars orbit in January 2004.

If Nozomi survives all these travails, the focus of its studies will be Mars's ionosphere and atmosphere. Among other things, scientists want to find out how the martian atmosphere leeches into space. The spacecraft also carries a camera to snap pictures of the planet and its moons.

Despite the broad international focus on Mars in 2004, don't think these missions will wrap up exploration of the Red Planet. NASA's Mars Reconnaissance Orbiter leaves Earth in August 2005, arriving at Mars in March 2006 to begin a science mission that concludes in July 2008. It comes equipped with a high-resolution camera that will return stereo images of the planet's entire surface down to an astonishing resolution of 12 inches. Italy plans to provide NASA with a shallow subsurface radar to look for underground ice and water.

In late 2003, NASA will select one of four proposals for its Mars Scout mission. The mission will launch in December 2006 for arrival in February 2009. One proposed Scout mission dips into the martian atmosphere to collect gas and dust samples on aerogel and return them to Earth for analysis. Another plan would orbit a spacecraft to look at atmospheric chemistry near the martian surface. Still another Scout design tailors a lander that looks for water and other volatile substances in specific locations on Mars. A final Scout idea proposes conducting a detailed search of Mars's atmosphere for evidence of microbial life, planetary water cycles, and active volcanism.

ESA's Mars NetLander leaves Earth in 2007 for arrival at Mars the following year. Four landers will establish a network of science stations around Mars, looking at the atmosphere, surface, and near subsurface. The four stations running simultaneously will unleash a torrent of data back to Earth via 2003's Mars Express and 2005's Mars Reconnaissance Orbiter.

Finally, in 2009 NASA plans to use technology that marries reliability with longevity in a lander. The Mars Smart Lander will feature autonomous guidance software that steers a descending lander past last-minute hazards for a successful touchdown. The rover it delivers will be powered by a nuclear generator and will be capable of cruising dozens of miles for a mission that could last years.

**THE BEAGLE 2 LANDER,** part of ESA's Mars Express mission, will touch down in December 2003 and begin searching for evidence of past or present life. ESA

# Journeys to the Moon and inner pla

ESA sets off on its first lunar mission with a summer 2003 launch. Smart 1 jostles between the Moon and Earth for 16 months before settling into a lunar polar orbit that varies between 180 and 6,000 miles above the Moon's cratered surface.

Smart 1 serves as a test bed for emerging European space technology. More than a dozen miniaturized instruments, including cameras and spectrometers, fit into a spacecraft the size of a 3-foot box. Smart 1 has an ion drive for orbital corrections, and it communicates with Earth through a prototype laser link. The mission spends about 2½ years in lunar orbit, measuring the Moon's composition and shooting photographic strips that will yield more detailed maps than currently available.

Japan's Institute of Space and Aeronautical Science (ISAS) delivers two penetrators to the Moon's surface between August and September 2004 as part of the Lunar-A mission. Both impact the Moon at 300 feet per second, burrowing 6 to 12 feet below the surface. Each will land along the equator, one on the Moon's near side and the other on the far side. Onboard accelerometers will track the forces that each probe experiences during impact to yield information about soil mechanics. For up to one year, batteries will power lunar seismometers as well as instruments that look at how heat flows through the lunar soil. Meanwhile, an orbiter will relay information to Earth, including maps of the Moon taken with a camera capable of revealing details as small as 90 feet.

Planetary astronomers are looking forward to finally heading back to Mercury more than three decades after Mariner 10 flew by in 1974 and 1975. March 2004 sees the launch of Messenger — the MErcury Surface, Space ENvironment, GEochemistry, and Ranging orbiter. (The cleverly crafted acronym plays on the god Mercury's role in Roman mythology.)

While Mariner 10 only briefly reconnoitered 45 percent of the planet's surface, beginning in September 2009, Messenger will orbit and scrutinize Mercury for one Earth year, or roughly four Mercury years. During that time, scientists plan to image the entire surface, stereoscopically in many places, down to a resolution of a few yards. Views through specially tuned optical filters will reveal clues about the planet's mineral make-up. A laser altimeter will create a relief map by timing how long it takes pulses of light to bounce back to the spacecraft.

Planetary geologists will also glean Mercury's chemical composition through two spectrometers that measure how the surface reflects x rays from the Sun and gamma rays from cosmic radiation. Another instrument looks in ultraviolet light to determine what constitutes Mercury's tenuous atmosphere. This same instrument senses surface minerals in visible and infrared wavelengths. A neutron spectrometer will look specifically for water ice, hints of which were detected by radio astronomers in 1991, at Mercury's poles. A magnetometer will yield insights into why Mercury is the only rocky planet besides Earth that has a global magnetic field.

Another experiment package will study the dynamics between the solar wind and Mercury's magnetic field and rarefied atmosphere. Lastly, the spacecraft's radio link to Earth will be a tool. Engineers can use shifts in frequency, caused by minute changes in the spacecraft's orbital motion, to map the planet's mass and crustal thickness.

Just a month before Messenger arrives at Mercury, ESA sets out on its own mission, dubbed BepiColombo, to the planet. The program actually involves three spacecraft: a planetary orbiter, a lander package, and an orbiter tailored specifically to study Mercury's magnetosphere. The trio cruises 2½ years before making planetfall in early 2012.

The planetary orbiter's cameras, laser altimeter, and spectrometers are similar to Messenger's but with an interesting addition of a telescope that detects near-Earth asteroids.

The magnetospheric orbiter — with its wave receiver, positive ion emitter, and deployable booms and wire antennae — builds on Messenger's studies of the interplay between Mercury's magnetic field and the solar wind. ESA includes an imager on this spacecraft, too.

A lander package rounds out the BepiColombo triumvirate. This segment combines a ballistic surface penetrator and a mini-rover. After diving from space, the penetrator will measure surface mechanical properties. It also features a seismometer to measure Mercury-quakes, a spectrometer that determines soil composition, and a heat-flow sensor to figure out thermal properties. The soft lander, slated to deliver a micro-rover, will be fitted with two cameras: one to capture scenes on descent and another that scrutinizes the landing area. Scientists hope battery-powered surface operations

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*Contributing editor* **John Shibley** *eagerly anticipates each new space mission.*

**THE MESSENGER SPACECRAFT** will begin a yearlong study of Mercury in 2009, photographing the entire planet and studying its chemistry and global magnetic field. NASA/JPL

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**MERCURY'S HEAVILY CRATERED SURFACE** has been viewed up close only by the Mariner 10 spacecraft, which imaged just 45 percent of the planet's surface. NASA/JPL

will last up to one week. Data will be relayed to Earth through either of BepiColombo's orbiters.

Venus gets a visitor when ESA's Venus Express enters orbit around it in April 2006 on a mission that lasts two Venus days, roughly 500 Earth days. Venus Express will fly an infrared spectrometer that peers through the clouds to measure temperatures and gases down to the planet's surface. It might spot erupting volcanoes, if Venus has any. A camera will return ultraviolet photos of venusian cloud patterns and track 180-mile-per-hour, high-altitude winds. A spectrometer will scan along Venus's sunrise and sunset terminators for trace gases in the planet's upper atmosphere. An onboard magnetometer will witness how the solar wind ravages the planet's upper atmosphere; Venus lacks a global magnetic field.

**THE MOON'S RUGGED TERRAIN** has welcomed just a few robotic visitors since the days of Apollo, including the Clementine spacecraft that snapped this image of Earth rising above the lunar limb. NASA/JPL

**THE VOLCANIC LANDSCAPE OF VENUS,** seen here in a view constructed from Magellan radar images, remains hidden beneath thick clouds. The Venus Express spacecraft will attempt to spy active volcanoes through the heat they release. NASA/JPL

# Of comets and planets,
# major an

ESA mounts the most ambitious expedition to a comet yet with the Rosetta mission. Rosetta will fly in formation with a comet for several months before settling into a 120-mile-high orbit around its nucleus. From this vantage point, the spacecraft will monitor activity as the comet approaches the Sun and comes to life. Almost a dozen instruments will sample the evolving gas and plasma environment and witness how the solar wind interacts with the comet's coma as things heat up. Imagers will comprehensively map both the comet's surface features and mineralogy.

Roughly six months into the encounter, Rosetta will drop a 200-pound lander onto the surface for even closer photography and analysis. Samples will be collected and brought onboard, where a camera will snap microscopic views for further chemical analysis. The mission will end about a year after the first encounter as the comet recedes from the Sun's heat and becomes dormant once more.

Currently, Rosetta mission planners are working through a bit of a quandary. The mission was supposed to launch in January 2003, but its Ariane 5 rocket booster was grounded due to a failure the month before. The launch window to Rosetta's primary target, Comet Wirtanen, closed in February 2003, leaving mission planners scrambling to find an alternative quarry. Rosetta's orbiter and lander, however, are precisely engineered for a comet of Wirtanen's size, solar orbit, and surface gravity. Back-up scenarios propose launching the spacecraft to Wirtanen in January 2004 or to a new target, Comet Churyumov-Gerasimenko, in February either of 2004 or 2005.

Meanwhile, NASA scientists patiently await the arrival of their comet-bound craft. It's been almost five years since Stardust left Cape Canaveral to rendezvous with Comet Wild 2. On New Year's Day 2004, the spacecraft will draw to within 90 miles of the comet's nucleus to capture surface details as fine as 90 feet in size. A deployable paddle containing aerogel cubes will gather dust as the spacecraft flies by. The paddle folds up into a return capsule that will parachute to Earth over Utah on January 15, 2006.

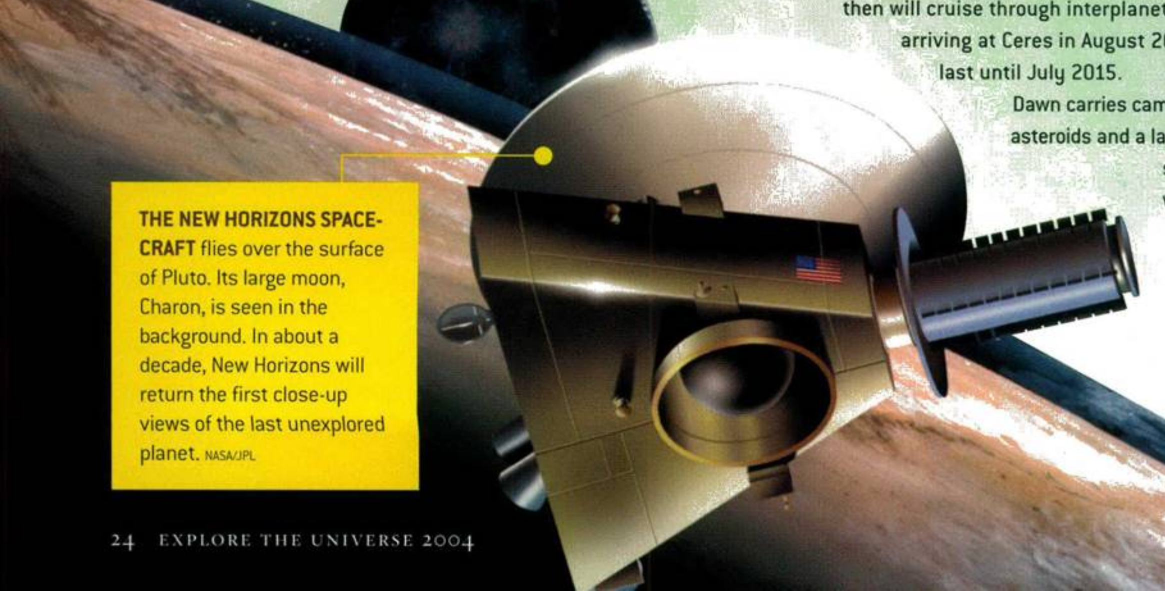
NASA plans another dramatic comet flyby when a mission dubbed Deep Impact sets off for Comet Tempel 1 in December 2004. On July 3, 2005, while closing in on the comet, the spacecraft will eject a 1-ton projectile toward the comet's surface at 6 miles per second. The following day's impact will blast out a crater as wide as a football field and up to 75 feet deep. Heat, gases, and light given off by the impact will be photographed and analyzed in real-time by the mother craft, which draws to within 300 miles of the comet several minutes after the hit. At closest approach, cameras should reveal detail down to 7 feet.

ISAS mounts Japan's first asteroid expedition with Muses-C. Given a May 2003 launch, the spacecraft will close in on asteroid 1998 SF36 in October 2005. After surveying the surface from 18 miles away, Muses-C becomes a soft lander. An oversized "horn" on the spacecraft will lightly touch the surface and fire projectiles that blast soil and shards of rock into a sample collector. Over the course of three months, Muses-C lifts off and repeats this landing and collection cycle two more times before eventually leaving 1998 SF36. A sample capsule lands in the Australian outback in June 2007.

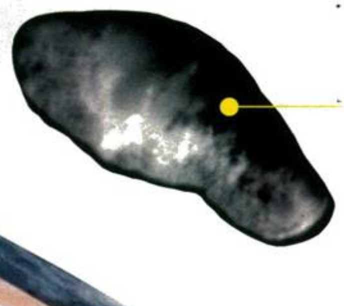
NASA's Dawn asteroid mission will tour two of the solar system's largest asteroids, Ceres and Vesta. These minor planets are completely different from each other. Planetary scientists think Ceres has a surface relatively unchanged from the early solar system, with an abundance of water-rich minerals and, perhaps, a thin atmosphere and frost. Vesta, however, possesses a much younger surface and could be the fragment of a larger planetoid that underwent radical geological change before fracturing.

Dawn launches in May 2006. Its orbital mission at Vesta lasts just under a year, between the end of July 2010 and early July 2011. The spacecraft then will cruise through interplanetary space for almost three years, arriving at Ceres in August 2014. The orbital stay at Ceres will last until July 2015.

Dawn carries cameras that will completely map both asteroids and a laser altimeter to precisely determine surface contours. Spectrometers will document the abundance of sur-



**THE NEW HORIZONS SPACECRAFT** flies over the surface of Pluto. Its large moon, Charon, is seen in the background. In about a decade, New Horizons will return the first close-up views of the last unexplored planet. NASA/JPL



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face minerals and their characteristics, while a magnetometer will investigate if either asteroid has global or isolated magnetic fields.

In the meantime, planetary scientists have been waiting almost seven years for Cassini to reach Saturn. This flagship planetary mission between NASA and ESA will give scientists not only a five-year look at Saturn and its ring system, but its huge family of moons as well. An ESA-built capsule named Huygens will even parachute into the atmosphere of Titan, the only moon in our solar system that has a thick atmosphere.

Cassini arrives at Saturn on July 1, 2004, entering a long, looping orbit around the planet that includes three flybys of Titan. Just over a week after the last Titan flyby, on December 25, Cassini releases Huygens. The probe's 22-day coast culminates with a January 16, 2005, landing on Titan. Its controlled descent through the moon's nitrogen atmosphere will be used for weather and chemistry measurements. A descent imager fitted with floodlights will take more than a thousand snapshots until Huygens either settles on solid ground or plunges into what could be an ocean of liquid methane.

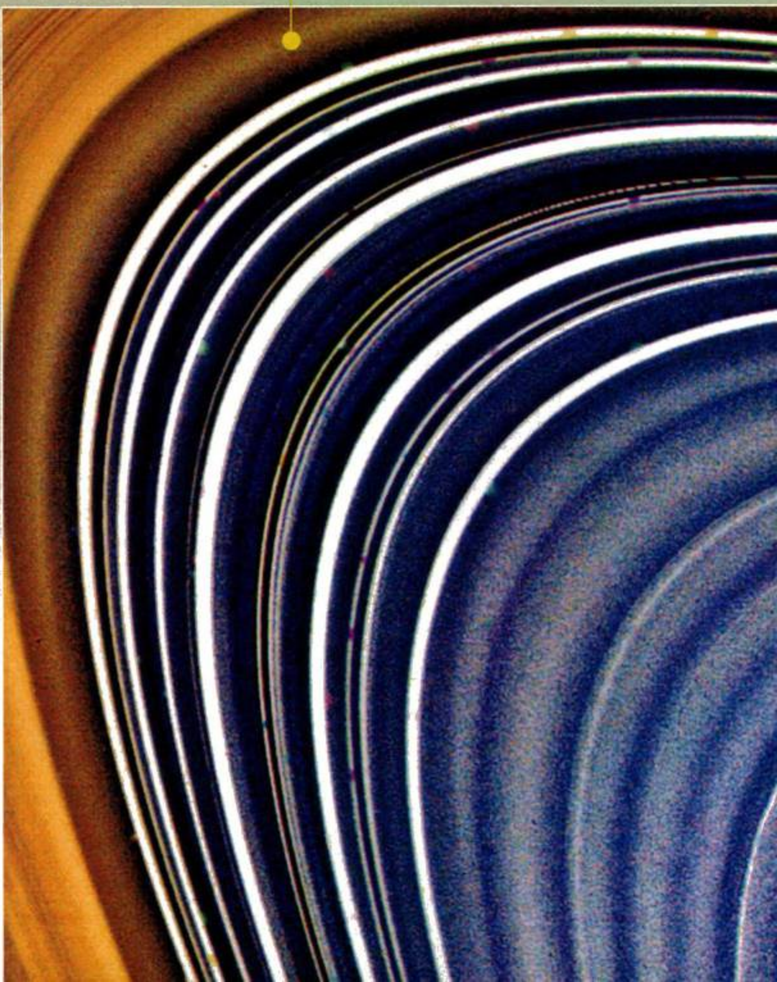
Cassini sails on overhead in saturnian orbit, relaying real-time data back to Earth from Huygens's plunge. Afterward, Cassini will settle into orbit for four years, yielding hundreds of thousands of photos of Saturn, its rings and ringlets, and 22 moons. As you would expect, a multitude of spectrometers will glean chemical and mineral compositions, while an extensive array of particle and field experiments will sense how the Saturn family interacts with one another and the solar environment.

Pluto is the only planet that has not yet been visited by a spacecraft. That's slated to change as early as 2015, when NASA's New Horizons conducts a flyby survey of Pluto and its oversized moon, Charon. Pluto intrigues planetary scientists because it's likely related to the far-flung Kuiper Belt, a primordial swarm of icy bodies first discovered in 1992.

New Horizons launches in January 2006 and gets a gravity boost from Jupiter the following March. The spacecraft flies to within 6,000 miles of Pluto and 17,000 miles of Charon in November 2015 or July 2016, depending upon what kind of rocket launches it from Earth. In the 75 days leading up to the flyby, the spacecraft will return pictures more detailed than the Hubble Space Telescope can take. The biggest data bonanza comes in the 12 hours on either side of closest approach. Details as small as 200 feet across will show up in photos.

After the Pluto flyby, between 2017 and 2024, mission controllers will nudge the spacecraft's trajectory so it can fly close to at least one Kuiper Belt object. Then it will join Pioneers 10 and 11 and Voyagers 1 and 2 on a journey into interstellar space.

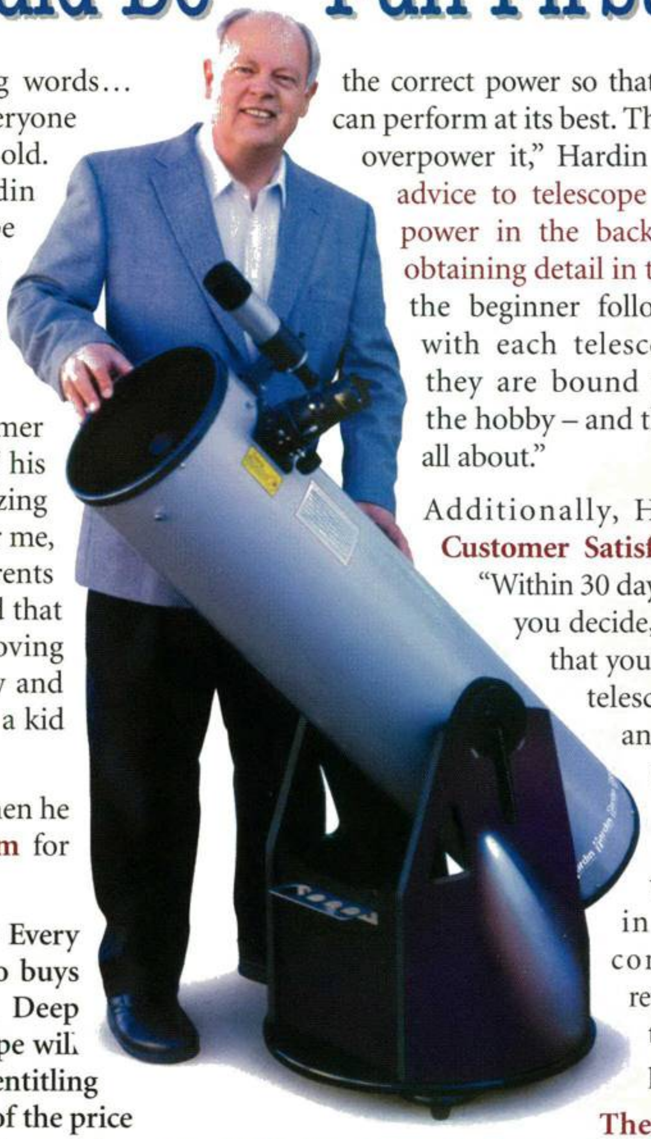
**THICK CLOUDS AND HAZE** block the view of the surface of Titan, Saturn's largest moon. The Huygens probe on Cassini will penetrate the clouds and land on Titan, giving us our first good look at this enigmatic moon. NASA/JPL



**THOUSANDS OF RINGLETS** unexpectedly turned up in Voyager images of Saturn. Now the Ringed Planet awaits the arrival of the Cassini orbiter, which seems destined to amaze planetary scientists all over again. NASA/JPL

**COMET BORRELLY APPEARS DARK** and textured in this view from Deep Space 1 — the best image ever taken of a comet's nucleus. A slew of upcoming comet missions promises to reveal these icy objects in unparalleled detail. NASA/JPL

# Telescopes Should Be Fun First...



Larry Hardin is known for not mincing words... especially when it comes to telescopes. "Everyone should have a telescope...even a five-year-old. You can never start too young," Hardin emphasizes. "The problem is, most telescope makers scare off beginners by emphasizing the science more than the fun. Amateur astronomy should be fun first; the science will come as the enthusiasm grows."

Larry Hardin has been an amateur astronomer and professional telescope maker most of his life. "When I was a kid, I remember agonizing over which scope would be my next one. For me, it was a huge investment requiring my parents to pitch in," he explains. "Then I discovered that telescope makers were constantly improving their models and I always wanted the new and larger versions. It was like that when I was a kid ... and it's like that today."

This is exactly what Hardin had in mind when he created his **Guaranteed Buy-Back Program** for his customers.

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**Here's how it works: Every Hardin customer who buys a six or eight-inch Deep Space Hunter telescope will receive a certificate entitling them to apply 50% of the price towards the purchase of a bigger and better telescope.**

"If they want to move up, they have one year to do this," states Hardin. "These telescopes are great places for the hobbyist to start. You'd be surprised just how much you can see with our basic six-inch Deep Space Hunter telescope."

Hardin continues: "When starting out, most telescope buyers are sold on the notion that the more optical power there is, the more you can see. That's nonsense! More power does not always result in seeing more detail. You can have lots of power and very little image detail."

Using a telescope is more art than science. Part of that art is choosing the correct power so that your telescope can perform at its best. That means don't overpower it," Hardin cautions. "My advice to telescope buyers is: Put power in the back seat and put obtaining detail in the front seat. If the beginner follows this advice with each telescope they buy, they are bound to truly enjoy the hobby – and that's what we're all about."

Additionally, Hardin offers a **Customer Satisfaction Refund**. "Within 30 days of purchase if you decide, for any reason, that you don't want our telescope, return it and we'll refund your money," he explains. "Understand that it must be in a 'like new' condition, and returned to us in the original packaging."

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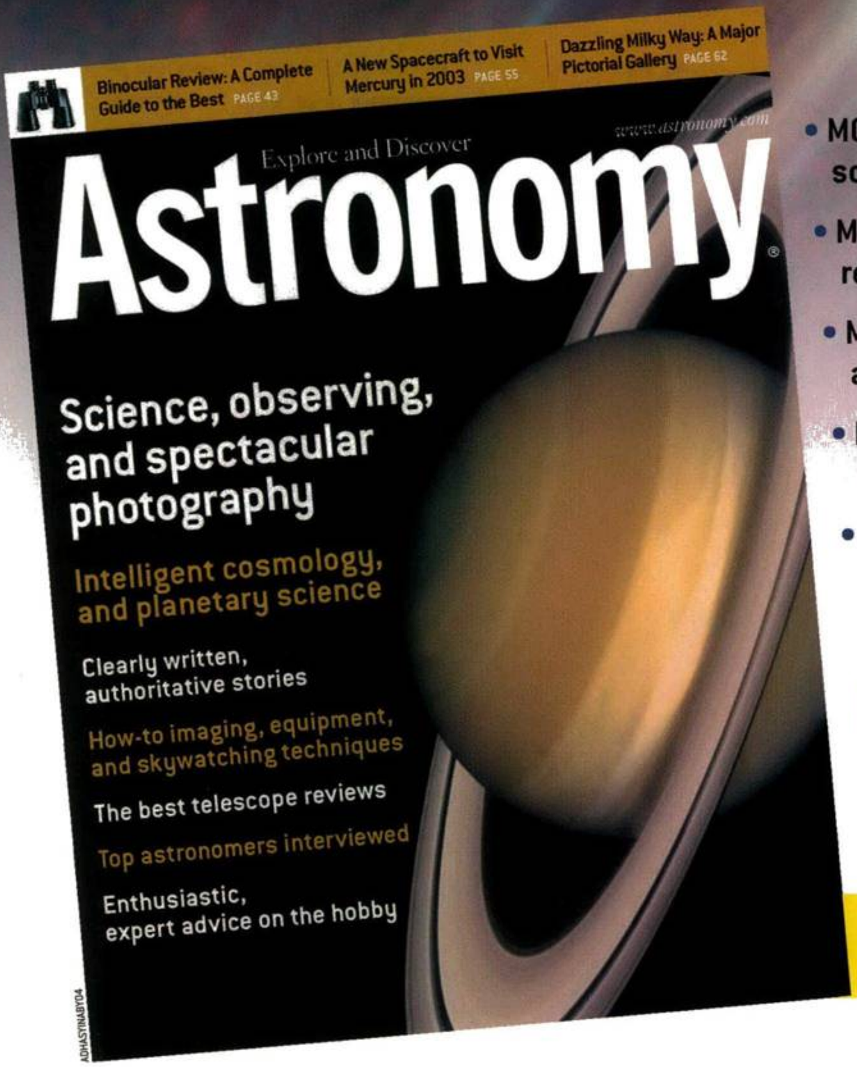
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# Ground-based telescopes vs. next generati

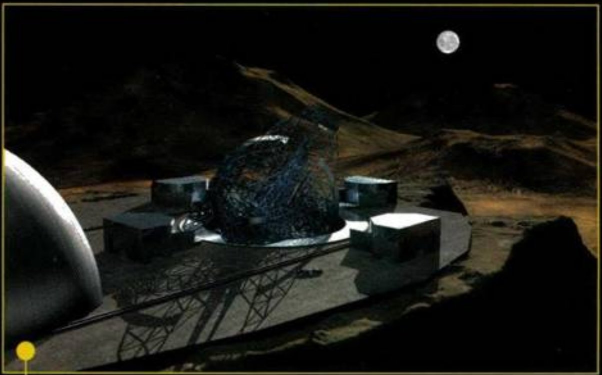
Technological advances have started the race between Earth-based observatories and high-flying orbiting telescopes. /// BY BILL SPIESMAN

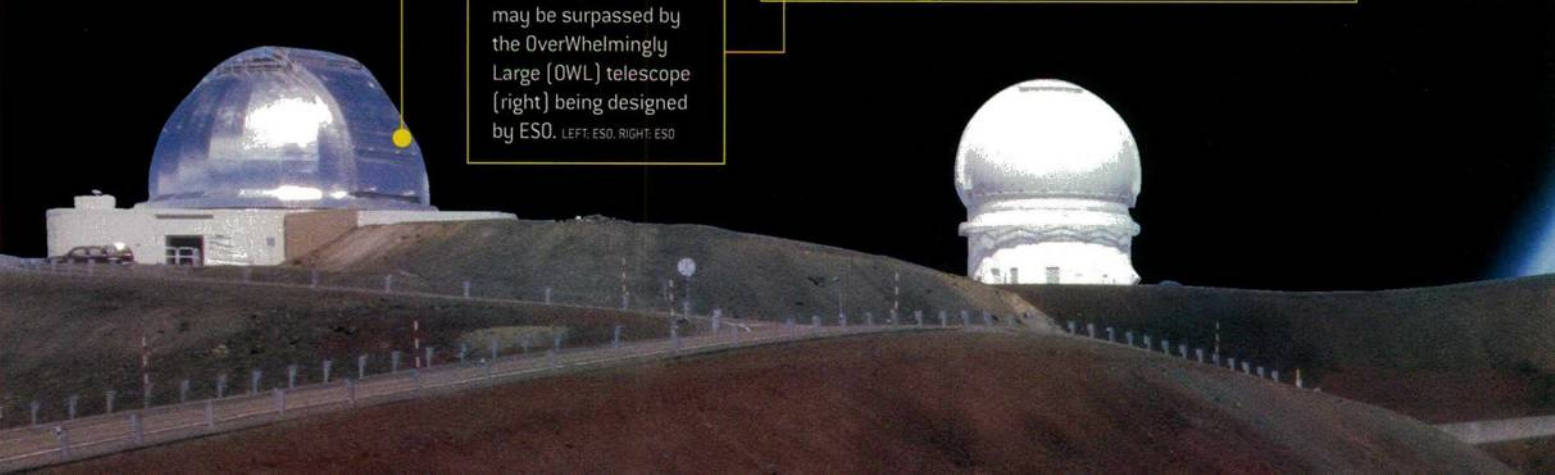
Astronomers are a greedy bunch. Given their druthers, they'd place a telescope on every dark mountain on the planet. They would clog low-Earth orbit with a bevy of astronomical observatories that would elude the blurring effects of Earth's atmosphere. But they can't. Astronomers aren't governments: They have fixed budgets to work with and limited amounts of time, and so they need to spend telescope dollars wisely.

Because of this, a new question has taken center stage in the astronomy world. Are ground-based telescopes or orbiting observatories better? For years, the answer seemed clear. The repaired Hubble Space Telescope (HST) clearly outdid its earthly competitors in terms of resolution and deep exposures that captured incredibly faint stars and galaxies. Getting above the soupy atmosphere really did make an astonishing difference. But over the past few years, high-grade adaptive optics systems now in place or planned on virtually all giant telescopes on the ground promise to equalize the race. The Subaru, Keck, and Gemini North scopes on Mauna Kea, Hawaii, for example, can effectively subtract atmospheric turbulence from their images and produce incredibly crisp details. The emergence of advanced technologies like adaptive optics means the question of how and where to build the next telescopes becomes more interesting as every new month rolls by.

## Goliaths of the ground

In terms of sheer area of light-collecting glass, the current record holder for the largest telescope system is the Very Large Telescope (VLT) in Paranal, Chile. This massive complex, operated by the European Southern Observatory (ESO), consists of four 8.2-meter instruments and several mobile 1.8-meter auxiliary telescopes. Together, the scopes work as one giant eye to image distant objects in the cosmos. The twin Keck telescopes on Mauna Kea, each measuring 10 meters across, currently hold second place.





**THE CURRENT GIANT ON THE GROUND** is the Very Large Telescope in Paranal, Chile (left), which has four 8.2-meter telescopes and a number of 1.8-meter auxiliary telescopes. Someday this telescope system's great size may be surpassed by the OverWhelmingly Large (OWL) telescope (right) being designed by ESO. LEFT: ESO. RIGHT: ESO

# on Hubble

**A DIMINUTIVE GIANT,** the Hubble Space Telescope's (left) primary mirror is just 2.5-meters across, but it is still the largest in space. In 2010, the James Webb Space Telescope (right), with its 6.5-meter mirror, will replace the HST. LEFT: NASA. RIGHT: NORTHROP GRUMMAN

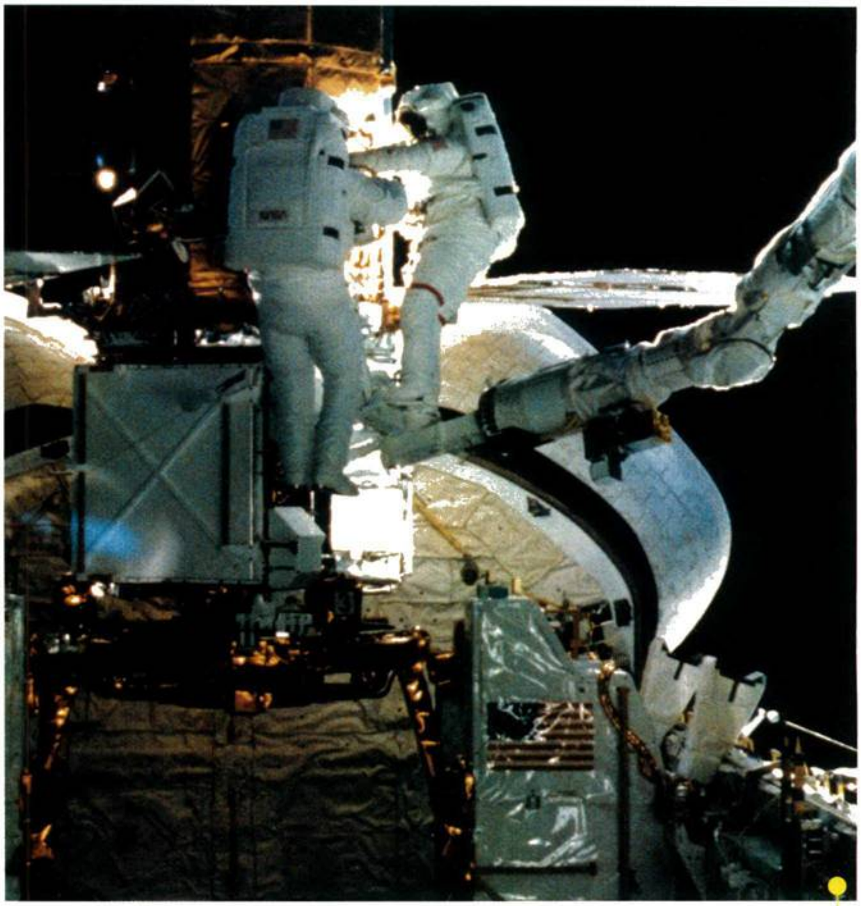
Size as a hallmark of great ground-based scopes came into being in the 1980s, when primary mirrors reached diameters approaching 5 meters. Above this critical threshold, mirrors no longer required optical finishing to an extreme degree of precision. Instead, the optical distortion a mirror experienced by sagging under its own weight became the main hurdle. New technologies, however, opened up a pathway around this longstanding problem.

In the decade of Big Hair and Ronald Reagan, the University of Arizona's Roger Angel, a pioneer in high-tech mirrors, developed a lightweight, stiff, honeycombed structure that could be used to support mirror blanks. These mirrors were spun-cast from chunks of glass in a giant rotating oven. This allowed the construction of larger and larger mirror blanks at a relatively small cost.

Engineers also devised segmented mirrors for such behemoths as the Keck telescopes and the Hobby-Eberly Telescope in Fort Davis, Texas. These systems employ light focused from a series of smaller segments into one instrument at the mirror's center, simplifying the cost and complexity of making large, monolithic mirrors. For these systems, sophisticated computers maintain the telescope's alignment on a particular target using edge sensors, lasers, and guide stars.

The push to build larger and larger telescopes continues unabated. The largest ground-based optical telescope project now being seriously considered is the 100-meter OWL Telescope (short for the OverWhelmingly Large Telescope), a project of ESO. While such mammoth instruments require immense funding and enormous collaborations between institutions, they can be built, at least in theory, because the natural resources and land area are available on Earth.

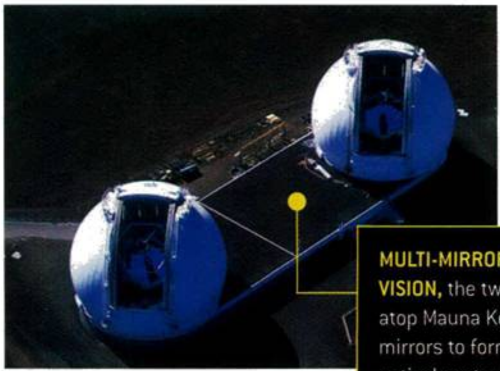
By contrast, space-based observatories are greatly limited in size by the vehicles needed to launch them and by their weight. With its modest 2.5-meter diameter mirror, the Hubble Space Telescope is the largest orbiting telescope today. A successor of sorts, the James Webb Space Telescope (JWST) will span 6.5 meters but won't be launched until 2010 at the earliest.



**"SPACE SHUTTLE TO THE RESCUE"** was the theme of STS-41C. During this mission, astronauts James D. van Hoften (left) and George C. Nelson (right) replaced the attitude control system and coronagraph electronics box on the Solar Max satellite. NASA

## Reach out and touch someone

Not only is it much easier to build large scopes on the ground, but they are a whole lot simpler to get to as well. While space-walkers can service and repair some space-based instruments like Hubble, a suspension of the space shuttle program like that following the Columbia disaster in February 2003 renders them unreachable. Conversely, the most remote ground telescopes — those at the South Pole or in the Chilean Atacama Desert — are comparatively easy to reach. Ground-based scopes will begin to lose this advantage only when humans working in space becomes commonplace — something science fiction has proclaimed is just around the



**MULTI-MIRRORED WITH "DOUBLE" VISION,** the twin Keck telescopes atop Mauna Kea use segmented mirrors to form the second largest optical system in the world, and they have the largest primary mirrors of any scope. KECK OBSERVATORY

**TOWERING FILAMENTS REACH OUT** from the core of NGC 3079. In this composite image, x rays (blue) trace out hot gas from a wind generated by the galaxy's supermassive black hole, while optical light (red and green) reveals the structure of the galaxy. NASA/CXC/U. NORTH CAROLINA/G. CECIL

corner for half a century now but reality describes as much more distant.

Accessibility means easy servicing. If a new digital detector fails on a ground-based scope, it can be taken back to a lab for repairs. A detector failure in space could spell the end of a mission. Ultimately, this could end the careers of those dedicated individuals who worked patiently for years prior to the actual launch hoping to obtain the mission's scientific results.

Orbiting scopes can be fixed, but the price is steep. A 1984 shuttle mission repaired the Solar Maximum Mission, but only after several nerve-racking attempts at capturing the wayward satellite. The eight-figure cost to repair a blown fuse was orders of magnitude greater than it would have been for a ground-based scope. In 1993, the shuttle made possible a very creative "fix" of the flawed mirror of the Hubble Space Telescope, which had been ground to the wrong shape based on a simple miscalculation. The telescope was repaired and has gone on to make some of the most incredible astronomical observations in history, but again at a steep cost.

## Keeping up with the Joneses

Once launched into orbit, space telescopes can't be updated very easily either. Without expensive, follow-up space missions, you pretty much need to stick with the equipment and instruments you started with — although several new instruments have been inserted into Hubble. The ease of access for ground-based scopes means updating to the latest technology is relatively straightforward. Test versions of ground instruments can be built relatively easily and then made progressively closer to final, shaking out any bugs or glitches along the way. Repeated trials at the telescope simplify instrument building because the test lab is at hand. This interactive engineering approach — a favorite for scientists — couldn't be done in space because all possible trouble needs to be anticipated and designed around before an instrument moves toward launch.

Because of this, space telescopes naturally lag behind their earthbound brethren when it comes to using innovative technologies. If unproven technologies are used for space scopes, the price can be huge: total mission failure.

## Resolving the past (and present)

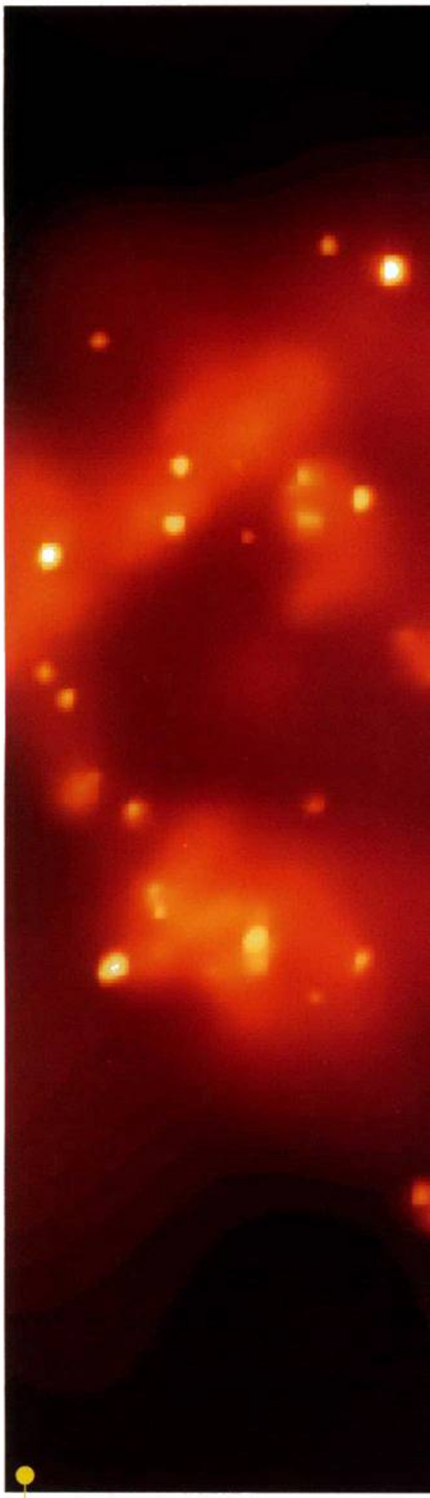
One of the most amazing aspects of new, high-tech, Earth-based scopes is their ability to compete with space telescopes in terms of resolution. Adaptive optics makes it happen. Earth's soupy atmosphere creates bubbles of warm and cool air that pass between stars or galaxies and the telescopes that receive their light. This distorts the images, making them fuzzy. Poor seeing, as astronomers term it, creates pictures of astronomical objects that roil with waves akin to the view of a road sign across a hot stretch of desert. However, adaptive optics' sensing equipment, which measures the atmospheric distortion, coupled with deformable mirrors, can effectively subtract most of the bad seeing from a star or galaxy image and sharpen the view.

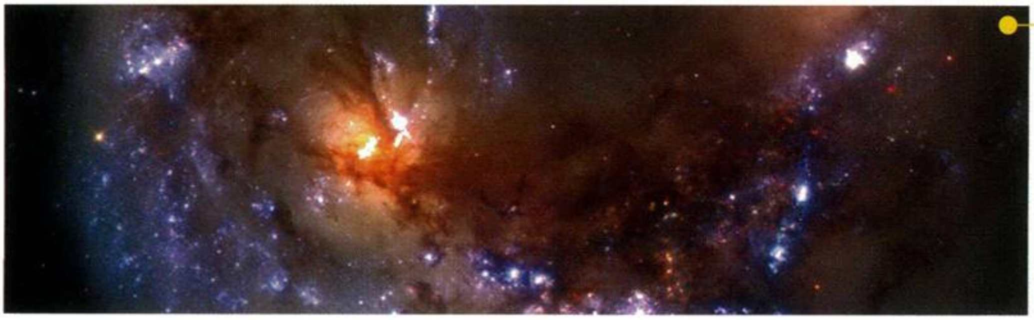
Adaptive optics stormed into the astronomy world in the early 1990s as a gift from the U.S. Department of Defense. Uncle Sam created these systems for spotting Soviet spy satellites and for targeting distant tanks. Eventually, the Air Force declassified its adaptive optics research, and astronomers began to take full advantage of clearer images. This diminishes the lead space telescopes had gained over ground-based instruments to the point where some of the largest scopes on Mauna Kea are imaging with resolution equivalent to the Hubble Telescope — and the VLT in Chile does slightly better than Hubble. But employing adaptive optics on Earth is pricey; with this technology, the cost advantage of ground-based scopes ebbs away a little.

## All the pretty colors

So what can space telescopes offer that can't be had on Earth for a lot less money? Although the remarkable sharpness of images created by Hubble is often touted as its main selling point, the VLT in Chile now rivals or exceeds that crispness. To identify the greatest advantage of a space telescope, step back for a moment to the birth of space-based astronomy.

After World War II, scientists at the Naval Research Laboratory in Washington, D.C., led by Richard Tousey, built several solar spectrographs to ride aboard captured Nazi V-2 rockets. They placed the first spectrograph in a V-2's nose, and inside the crater that formed when the warhead





**POCKETS OF HIGH-TEMPERATURE GAS** that stand out in this x-ray image (above) of the Antennae galaxies (NGC 4038 and NGC 4039) in Corvus, taken by the Chandra X-ray Observatory, blend in the HST optical image (left).

X-RAY: NASA/SAO/CXC/G. FABBIANO ET AL. OPTICAL: NASA/HST/WHITMORE ET AL.

landed on Earth, scientists found they had obtained the first ultraviolet spectrum of the Sun. Subsequently, scientists placed spectrographs in the rockets' tail fins, which were designed to break free on the V-2's return to Earth, to make recovery easier. The first recovered ultraviolet spectrum of the Sun (210 to 300 nanometers) was made on October 10, 1946, and it revealed features in the Sun's atmosphere. That instrument had very poor resolution, yet the information it recorded still is unobtainable from the ground because Earth's atmosphere blocks the ultraviolet part of the spectrum.

So, low-Earth orbit will always offer the advantage of recording parts of the electromagnetic spectrum that just can't be seen down here on the surface. Imagine astronomy as a science without any observations in the x-ray, ultraviolet, or infrared wavelengths — we would be missing a large part of the story without them; we would see what amounts to a black-and-white picture of a full-color universe.

One of the most successful of all space telescopes was the International Ultraviolet Explorer (IUE). Launched in 1978, this small telescope operated years past its scheduled shutdown, finally dying in orbit after collecting nearly 19 years' worth of data. It was replaced by a new ultraviolet instrument, the Goddard High Resolution Spectrograph that flew aboard Hubble until 1993. Similarly, infrared telescopes such as the Infrared Astronomy Satellite (1983) and the Cosmic Background Explorer (1990) opened up a new world of infrared astronomy, a world of interstellar dust and cool gas. These observations revealed hidden realms deep within star-forming regions. The newest set of instruments on Hubble enables infrared imaging, and the James Webb Telescope will carry a suite of infrared detectors.

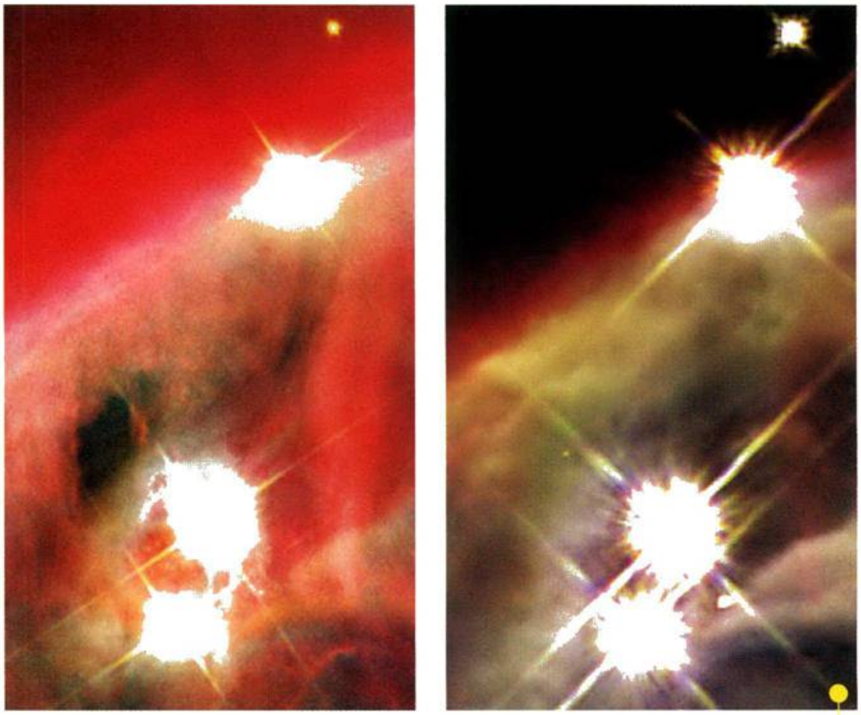
While orbiting several hundred miles above Earth's surface benefits many infrared detectors, some must travel much farther afield to escape the atmospheric effects of Earth as well as radiation from the Sun. The Wilkinson Microwave Anisotropy Probe (WMAP), launched in 2001 and set to measure the temperature over the whole sky, orbits at Lagrangian Point 2 (L2). Some four times farther away than the Moon, L2 is a gravitational well that serves as a stable point far from Earth's atmosphere. Located behind Earth from the Sun's point of view, L2 is shielded from solar radiation. The Webb Telescope will also be deployed to this position; NASA's Space Infrared Telescope Facility (SIRTF), set for launch in August 2003, will keep its mirror cooled by continually maneuvering there also.

For all Earth's luxuries, our planet can't provide a platform that can be permanently shielded from sunlight; nor can it afford a view of objects in the infrared, x-ray, or ultraviolet wavelengths. Gravity is a fact you can feel just by standing on our planet. Some of the greatest missions humans have designed, however, have taken advantage of the absence of gravity in space to bring us a new window into these hidden worlds.

## The pros and cons

Is there a clear winner between space-based and ground-based telescopes? So much of what

**Bill Spiesman** *is a research scientist working on SIRTF at the University of Texas at Austin. He is also a pilot in the National Guard and submitted parts of this story while called up to active duty.*

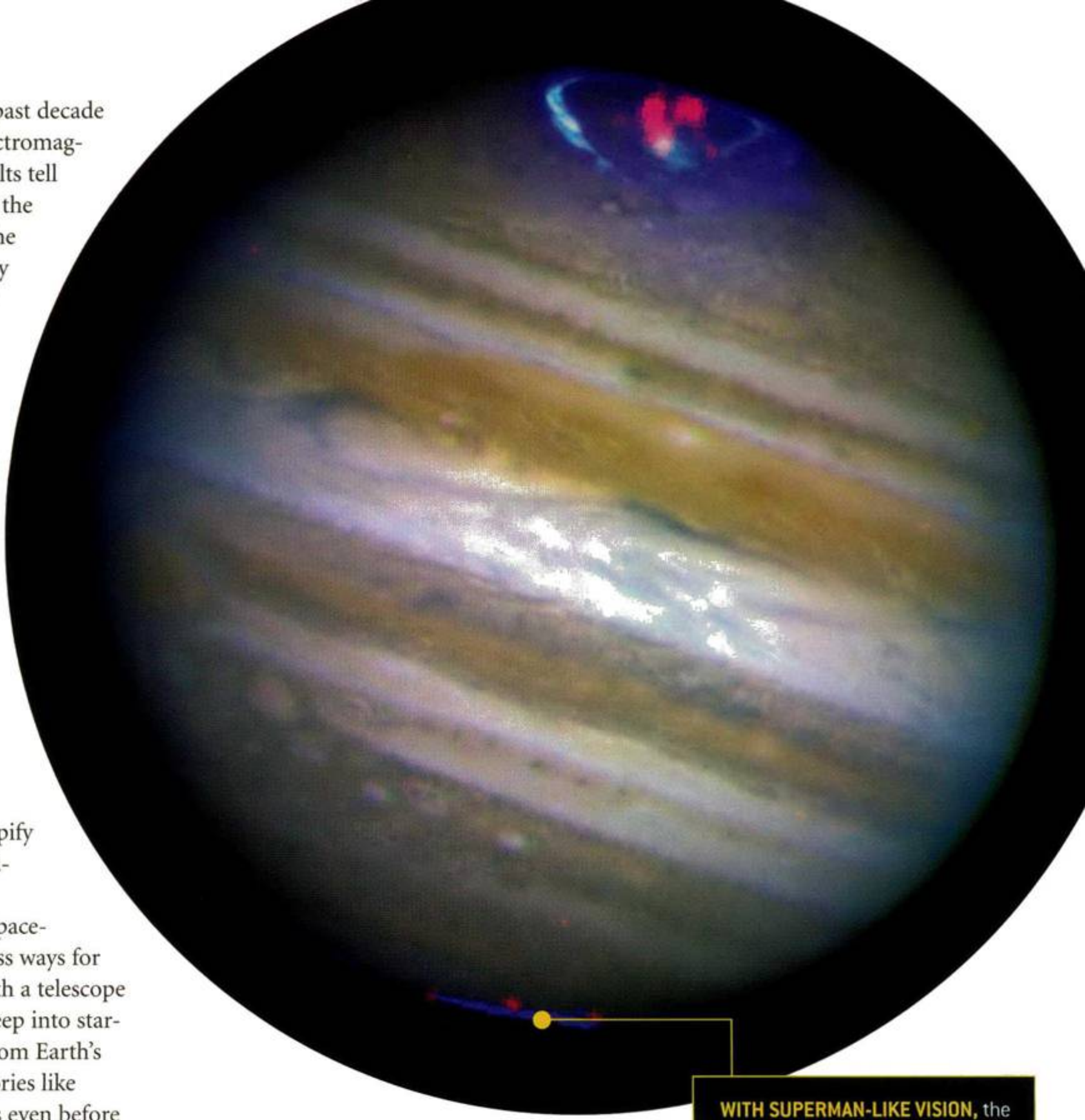


**STARS IN THE CONE NEBULA** are hidden by gas and dust in this visible light image taken with HST's ACS (left). An infrared image taken with HST's NICMOS (right) uncovers them. NASA/NICMOS GROUP

**ULTRAVIOLET OBSERVATIONS** reveal regions of hot gas in these galaxies seen with HST's WFPC2. *Left:* NGC 3310. *Center:* ESO 418–008. *Right:* UGC 06471 and UGC 06472. NASA/ROGIER WINDHORST (ASU)/THE HUBBLE MID-UV TEAM astronomers have learned over the past decade has come from access to the full electromagnetic spectrum. Recent WMAP results tell astronomers about the evolution of the early universe. Observations from the orbiting Chandra X-ray Observatory and from Hubble have revealed the long-suspected presence of black holes in many massive galaxies.

In the nearly 400 years since Galileo turned his telescope skyward, astronomers have made countless discoveries from the ground. As time marches on, the nature of the discoveries becomes more specific and less obvious. The era of individual discoveries from pointing a telescope in the right place will slowly wind down as the age of discoveries arising from complex statistical analyses surges ahead. Such amazing finds as the discoveries of more than 100 extrasolar planets typify the complex realm of where ground-based astronomy is headed.

Because of its nature, however, space-based astronomy still offers countless ways for individuals to make discoveries. With a telescope like SIRTF, astronomers will peer deep into star-forming regions that are invisible from Earth's surface. Raw images from observatories like WMAP reveal startling new insights even before astronomers computer-process them. Answers that might come from ground-based instruments and laborious study arise in an instant from orbiting telescopes. Other discoveries that have been made in space simply could not have been made from the ground.

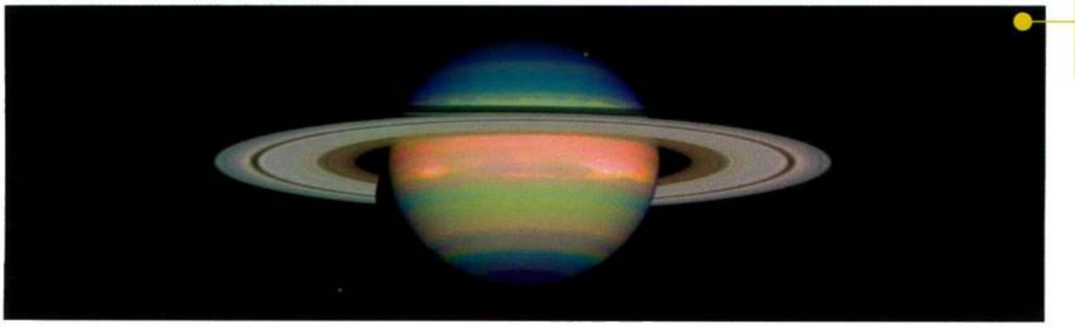


**WITH SUPERMAN-LIKE VISION,** the Chandra X-ray Observatory peers at Jupiter and detects its x-ray emissions (pink and blue), while the Hubble Space Telescope takes ultraviolet exposures of the planet (main image). X-RAY: NASA/SWRI/R. GLADSTONE ET AL., UV: NASA/HST/J. CLARKE ET AL., OPTICAL: NASA/HST/R. BEEBE ET AL.

### Tomorrow's astronomy

The future of astronomy certainly includes ground-based observatories. But the real winner will be space. The Space Interferometry Mission, when launched in 2009, will measure the positions of stars 1,000 times more accurately than any Earth-based telescope. This will uncover Earth-like planets orbiting nearby stars in the Milky Way. The Terrestrial Planet Finder mission, on the launch docket for 2012 through 2015, and arrays of space-based scopes not only will image terrestrial planets orbiting nearby stars but also will capture spectra of their atmospheres. These data will provide a good hint as to whether living beings inhabit the distant worlds.

The gentle giants of the ground, peering up at the cosmos from their mountain peaks and desert plains, will remain astronomers' critical test beds. They will continue as workhorses, surging ahead with redshift surveys, monitoring distant supernovae, and cataloging orbital periods of distant planets. But the new realm, the cutting edge of astronomy, is being lifted into space and may never return. ■



**DELINEATED LAYERS OF CLOUDS** appear in this infrared image of Saturn that was taken with HST's NICMOS camera. The main cloud layer is blue; green and yellow indicate a haze, while red and orange colors indicate high-level clouds. ERICH KARKOSCHKA (UNIVERSITY OF ARIZONA), AND NASA

# I have a scope, now what do

The very vastness of space can be daunting to new telescope owners. Use this quick-start guide to get your bearings. /// BY ROBERT BURNHAM

# I do?

Buying a telescope is a big step and a huge thrill, but it also can be somewhat scary. Telescopes are no small investment. Now that you've spent all that money, where do you even begin? The first step is easy: Take a deep breath. No one is going to see everything on the first observing run — or even on the hundredth. So take that beautiful new instrument out for a spin around the sky. Try to set it up where you won't be looking across warm rooftops or other heat sources that produce view-distorting air currents. Wait about half an hour for the scope to adjust to the outdoor temperature, and while you're waiting, look up to see if you recognize any celestial guideposts.

Sky maps for 2004 start on page 43. (To read them while saving your night vision, buy a dim, red-lensed flashlight or make one with colored cellophane.) Can you find the Big Dipper? The outer stars in its bowl point to Polaris, the North Star. Now face south and look for Orion (in winter), Leo (in spring), Scorpius (in summer), or Pegasus (in fall). These recognizable figures can help you locate others, and even the bright skies over the suburbs should display enough stars to get you oriented.

Stars appear to drift from east to west, matching the Sun's daytime motion. Watch the North Star over a period of time, and you will see stars creeping around Polaris like a giant clock running in reverse.

Constellations, areas of the sky often associated with mythological figures, also slip westward as weeks pass, reflecting Earth's progress in its year-long orbit around the Sun. The difference from one day to the next is small — about four minutes — but it adds up. After a month, constellations rise two hours earlier and set two hours sooner. Thus, in October, Orion rises around midnight, while in February it stands high in the southern sky by nightfall.

Let's start our sky tour with one target everybody knows — the Moon.

## Our satellite

It's an ideal "first light" object for new telescopes: big, bright, and packed with detail. No other world shows you so much. Indeed, some backyard astronomers hardly get beyond the Moon, spending years exploring its battered surface, a relic of the solar system's chaotic early days.

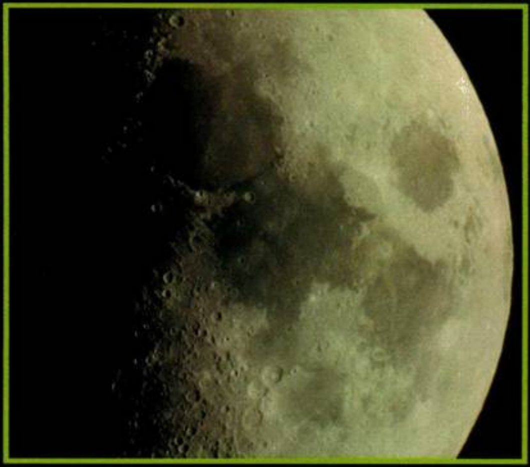
For your first views of the Moon, keep telescope magnifications low — no more than 25x per inch of aperture — so unsteady air and vibrations don't dominate the view.

Surprisingly, the best time to look is not during Full Moon, but around the two quarter phases. Observe near the terminator (the line marking lunar sunrise or sunset), where light strikes the surface at shallow angles, bringing out the beautifully intricate topography. Craters, mountains, faults, and steep slopes called scarps are all starkly drawn in light and shadow and seem to reveal subtle new details with every viewing.

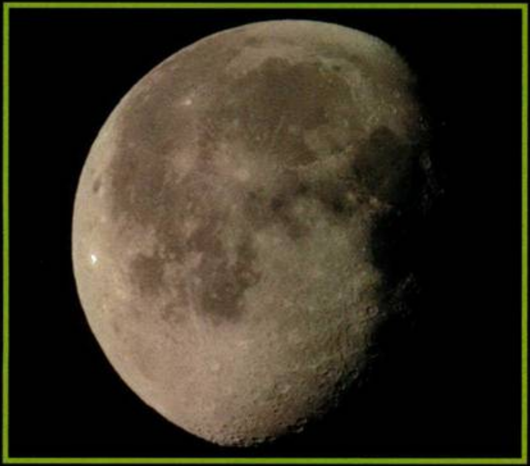
First Quarter, in which the eastern half of the lunar face is illuminated, shows several dark splotches that early observers took for dry ocean beds. These were named using the Latin word for sea, *mare* (MAH-ray): Mare Tranquillitatis, the Sea of Tranquility; Mare Nectaris, the Sea of Nectar; and so on. In reality, these are thin sheets

**THE PLANETS WERE IN ALIGNMENT** on New Year's Day in 1998. Below a crescent Moon, Jupiter, Mars, and Venus (from left to right) were visible to the naked eye, but observers with telescopes also saw Uranus and Neptune in the lineup. The planets fall into orderly formation along the ecliptic because they all share essentially the same orbital plane around the Sun. TIM BARNWELL

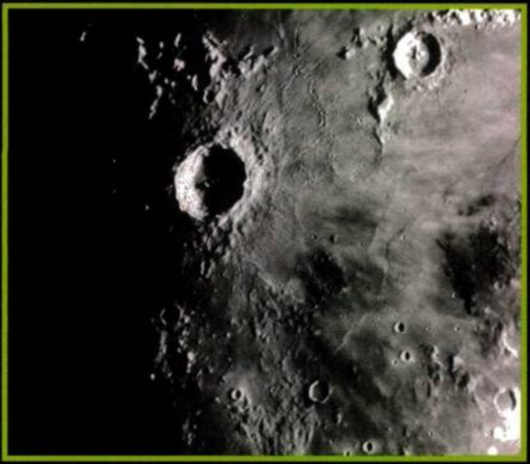
**CATCH AN OCCULTATION** with your telescope when the Moon passes in front of other objects, such as Jupiter and its brightest moons (top) or Saturn (bottom). *Top*: Reflected sunlight caused the glare on the crescent Moon in this long exposure. TOP: J. GUERTIN AND R. BALDRIDGE / BOTTOM: CHRIS COOK



**FIRST QUARTER MOON** is an excellent time to view the lunar maria — dark, lava-filled basins originally gouged out by meteorite impacts. The first astronauts to land on the Moon touched down in Mare Tranquillitatis (center). MARK SCHMIDT



**BRIGHT RAYS** of ejected rock radiate from the craters Copernicus (near center) and Tycho (lower left) when sunlight illuminates the western face of the Moon. Lava once flowed between the maria north of Copernicus. DAVID D. ANDERSON



**SUNRISE ON THE MOON** exposes texture and depth in and around the craters Copernicus (center) and Eratosthenes (upper right). A 6-inch f/12 refractor was used to take this two-second exposure. LEE C. COOMBS

of lava filling broad, shallow basins excavated by big meteorite impacts. The first manned lunar landing occurred in Mare Tranquillitatis, but unfortunately, the landers left by Apollo astronauts are too small to see from Earth. This year, view First Quarter Moons in the evening hours toward the end of each month.

Last Quarter Moons are best before dawn and occur around mid-month in 2004. Their landscape is dominated by a giant lava sheet called Oceanus Procellarum, the Ocean of Storms, which formed when lava overflowed from Mare Imbrium, the Sea of Rains. Probably the most striking sight on the Moon's western hemisphere is the crater Copernicus. During the two-week lunar "day," sunlight plays across this feature unforgettably. Sunrise at Copernicus reveals an inky pool surrounded by a bright rim; walls and terraces emerge as sunlight spills inside to reveal the crater's flat floor and central peaks. High noon (at Full Moon) flattens the scene but reveals a splash-pattern of streaks that radiate like flower petals. Called "rays," these are lines of shattered rock ejected by meteorite impacts.

The Moon's largest ray pattern centers on the crater Tycho, which is "only" 109 million years old, a fraction of the 880-million-year-old Copernicus, which was dated using samples gathered by the Apollo 12 astronauts. Full Moon highlights these bright rays, as well as light and dark variations — often from lava flows — in the maria.

## Touring the planets

Because they move in relation to the stars, planets might seem difficult to locate. But you will always find them within a band of constellations that straddles an imaginary line called the ecliptic. This is the plane of Earth's orbit projected onto the sky, and the planets seem to follow this path because they more or less share our orbital plane.

Orbiting closer to the Sun than Earth, Mercury and Venus appear only briefly before sunrise or shortly after sunset. City-dwellers hardly ever see Mercury because it's usually near the horizon at twilight. Catch this year's best views of Mercury in the evening sky from mid-March to early April and at dawn from late August to late September. Telescopic observing "windows" last a week or two around these times. Through a telescope, Mercury looks like a pinkish-gray disk with phases like the Moon's.

Venus is much more prominent — it shines brightly in the evening from January to June and in the morning from July to November. Its volcanic surface is shrouded in thick white clouds, so through a telescope, Venus displays a bland disk that slowly changes shape as it undergoes phases.

The other planets remain visible for months at a time, although Uranus, Neptune, and Pluto can be spotted only through a telescope. Our neighbor Mars shares striking similarities with Earth — it has seasons, polar caps, deserts, volcanoes, and a day that's just half an hour longer than ours. Through a telescope, its size and brightness vary depending on its distance. With experience, you can track changes in clouds, dust storms, and the polar caps. Dark markings — fields of lava and boulders — come and go as fine dust blows across them. The best telescopic views of Mars approximate the Moon's naked-eye appearance.

Jupiter is the largest planet, and it marks a change in kind. Huddled near the Sun, Mercury, Venus, Earth, and Mars are all small and rocky. Jupiter is the first of the four "gas giants," massive worlds of hydrogen and helium wrapped around rocky cores. With more than 300 times the mass of Earth, Jupiter (as well as each of the other three hulking members of this group — Saturn, Uranus, and Neptune) governs a miniature solar system of moons and rings.

Jupiter shines brighter than any star and is a splendid telescopic sight. Through a telescope or binoculars, four pinpoints of light flank its disk — these are the largest of its many

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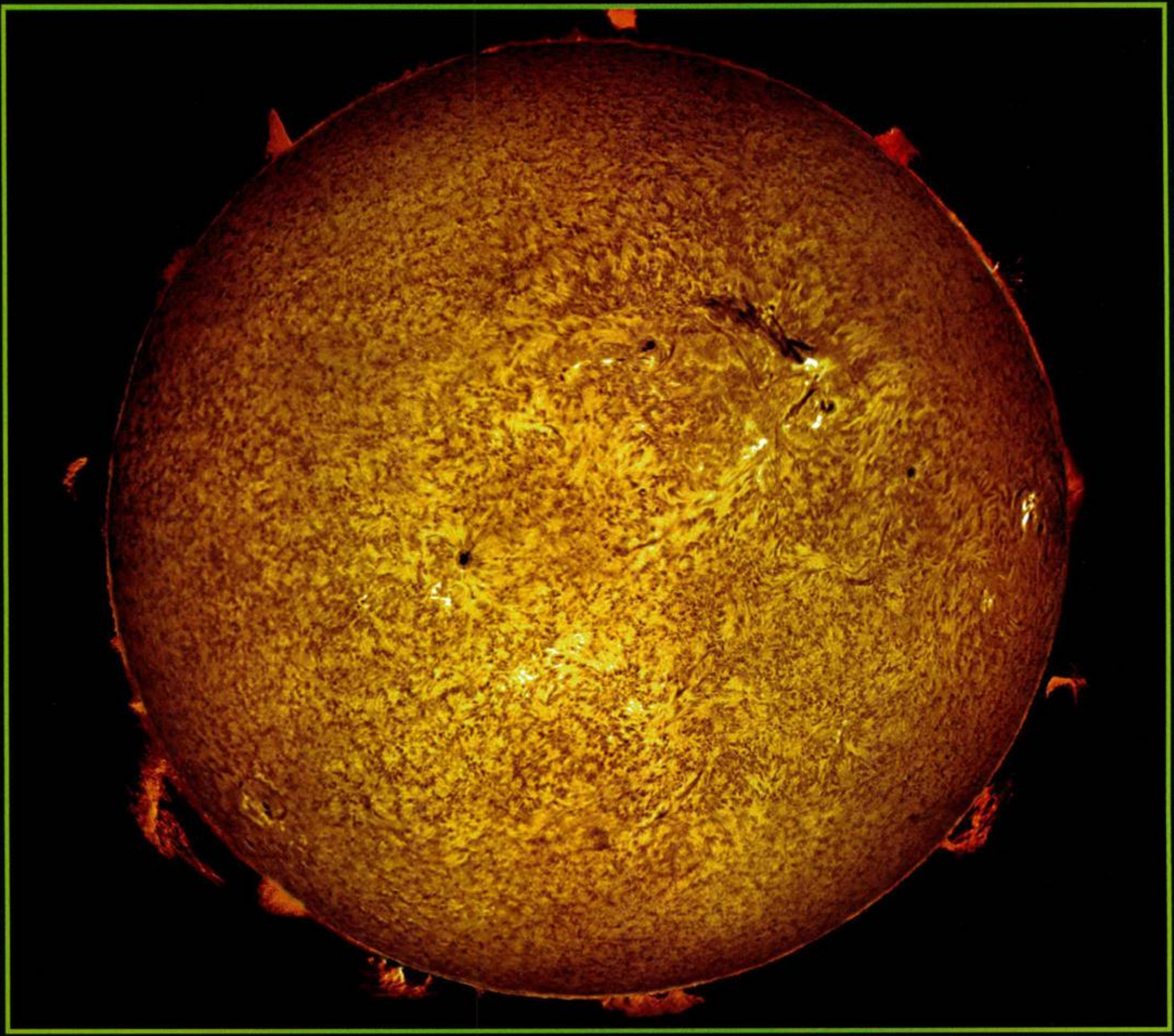
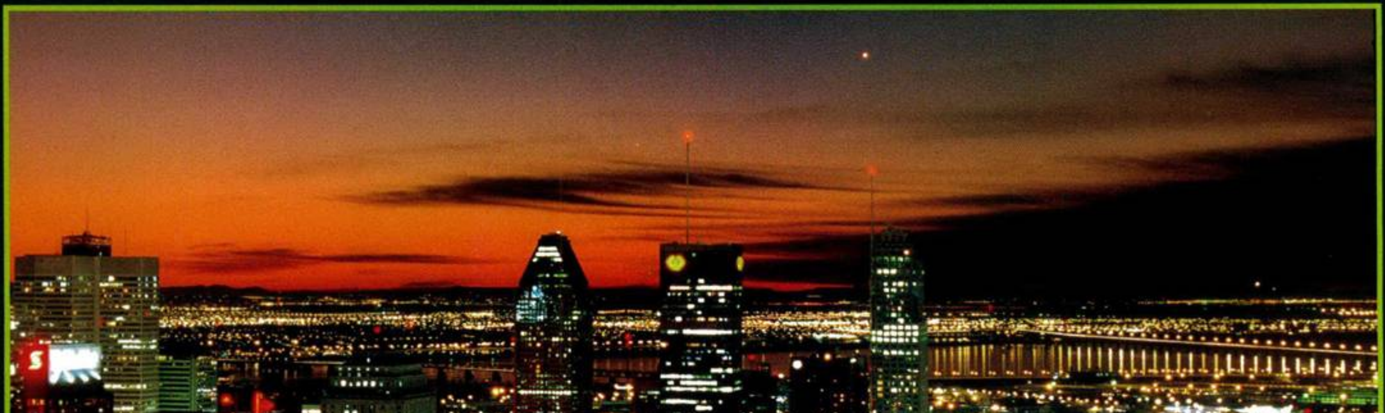
**Robert Burnham** *is a contributing editor of* Astronomy. *His book* Exploring the Starry Sky, *a beginner's guide to the constellations, was published in 2003.*



**OBSERVE DURING THE DAY** with special filters that protect your telescope — not to mention your eyes — from the Sun's intense radiation. This image was taken through a 7-inch refractor with a filter that transmits only wavelengths of 656.3 nanometers. Powerful magnetic fields govern much of the Sun's dynamic features, including dark sunspots and leaping prominences. JACK NEWTON



**LIGHT POLLUTION** makes deep-sky observing nearly impossible from cities, but urbanites may still get good views of the planets if the seeing is steady. *Above*, Mercury (center) and Venus (right) shine in the dawn sky above Montreal. G. LIVADARAS

**DYNAMIC MARS,** with its dust storms and ice caps, is probably the most interesting telescopic target of the four terrestrial planets. Track its changes from night to night by sketching what you see through your eyepiece. J. ASZTALOS

**JUPITER GYRATES** on its axis once every 10 hours, pulling bands of gas along with it. The planet appears brighter than any star, and its four largest moons, Io, Europa, Ganymede, and Callisto, can often be seen alongside it. DONALD C. PARKER

**LIKE GIANT, ICY HULA HOOPS,** Saturn's rings tilt 27° with respect to the planet's orbital plane. So as the planet circles the Sun every 30 years, observers can see the rings from above, below, and edge-on. DONALD C. PARKER

moons (61 identified at press time). The "Big Four" pop in and out of view as they shuttle around the planet. From Jupiter outward they are Io, Europa, Ganymede, and Callisto.

Jupiter's "surface" is the top of an immense atmosphere of hydrogen, helium, and other gases. Its rapid rotation (less than 10 hours) makes it look distinctly oval and has torn its clouds into dark belts and light zones, within which drift circular storms as big as Earth or larger. One such tempest, known as the Great Red Spot, has been visible for the last 300 years.

Saturn is a smaller, dimmer Jupiter with an ivory cast. With a colder, less active atmosphere, its cloud bands are less visible. Saturn's biggest moon, Titan, has an atmosphere denser than our own. Visible even through binoculars, Titan orbits Saturn every 16 days.

Yet Saturn's biggest draw is the most beautiful set of rings in the solar system — the only set visible through backyard telescopes, and a sight you'll never forget. The rings span about twice Saturn's diameter and are inclined to its orbit by about 27°. (Currently we see their southern side.) The rings, swarms of ice particles mixed with rocky dust, appear to divide into three bands: the outer A ring, the broad B ring, and the innermost C ring, which is hard to see.

Uranus and Neptune, discovered in 1781 and 1846, respectively, are smaller than Jupiter and Saturn but are similar in composition. Methane in Uranus's atmosphere lends it the bluish-green tinge you see in the eyepiece. Neptune mirrors Uranus; telescopes reveal it as a bluish dot.

The farthest planet is Pluto, discovered in 1930. Made of ice and rock, it is only two-thirds the Moon's size. Seeing Pluto requires a telescope at least 8 inches across, and even then, the tiny body simply looks like a star.

## Our local star

Before leaving the solar system for deep space, take a look at our own star. Solar observing differs greatly from nighttime viewing because the telescope must be rigged to handle the Sun's fierce light. Use a solar filter that fits over the telescope's front end to keep the Sun's heat out of the optics. Cover the finder with a cap and aim the telescope by minimizing its shadow on the ground.

With a filter, you can use regular eyepieces to explore the Sun's visible surface, called the photosphere. The center of the disk looks brighter than the edge because at the center you look deeper into the Sun, where temperatures are higher. In the photosphere, rising plasma forms a honeycomb-like texture called granulation. This upwelling causes individual plasma cells to pop in and out of existence every few minutes or so.

The most famous solar features are sunspots, places where the photosphere is cooler and highly magnetized. Sunspots vary in size, shape, and complexity — from single black dots to complicated groups. Most, however, show up in pairs.

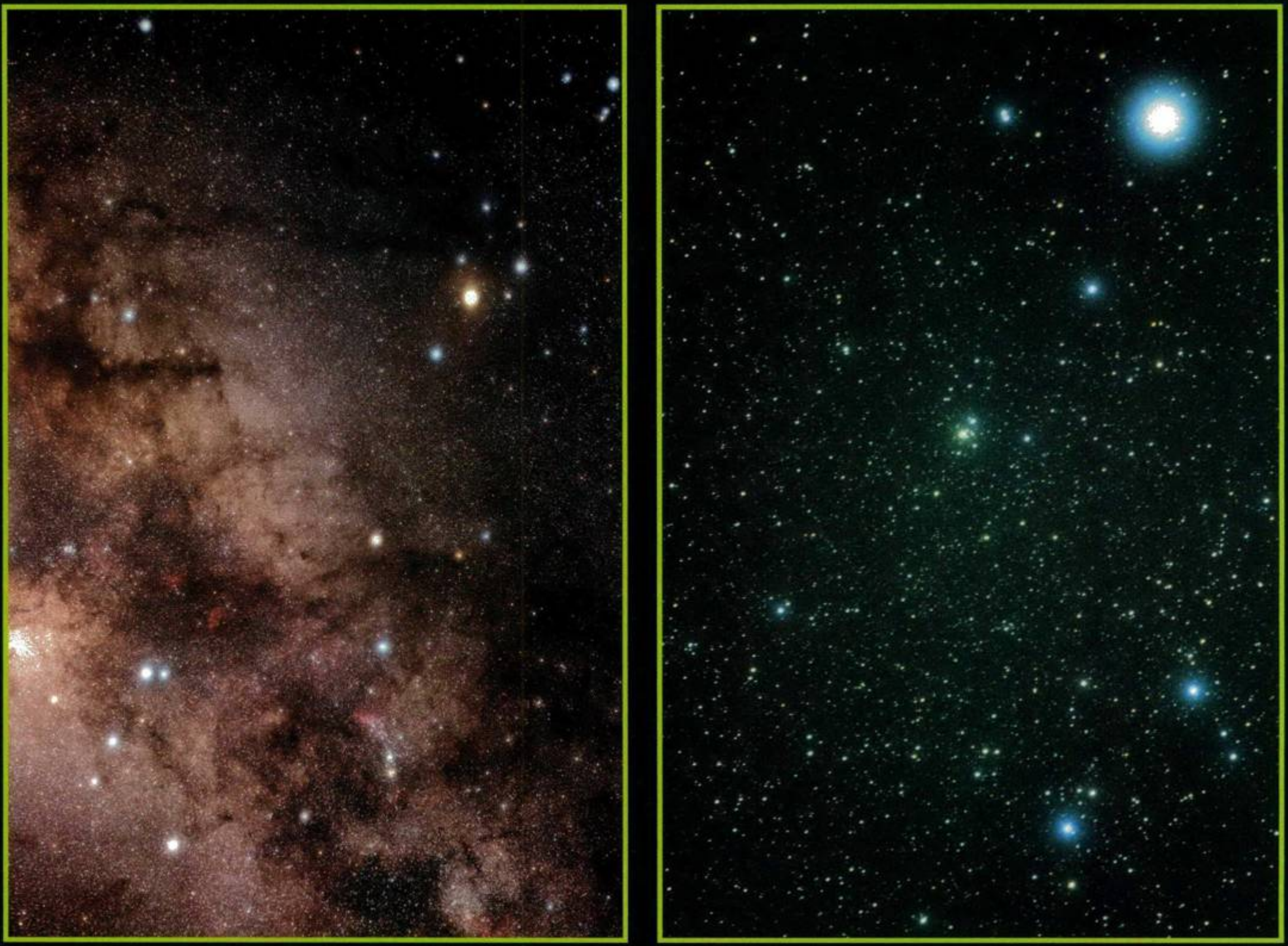
A typical sunspot has a dark inner core called the umbra and a surrounding collar called the penumbra. The Sun's rotation ensures that a typical sunspot spends about 10 days in clear view. During this time, you can watch the spot or group evolve.

The Sun doesn't end at the photosphere. Above it lies a thin, cool, pinkish layer called the chromosphere, visible only during total solar eclipses. The chromosphere merges into the corona, the Sun's vast outer atmosphere, which also is visible only during total eclipses.

## The deep sky

When you focus your telescope beyond the solar system and into deep space, the objects lie much farther away and appear much dimmer. Their distance isn't a problem per se; their brightness can be. For planetary observing, steady seeing is far more important than a dark sky. But for deep-sky observing, it's the other way around. Seeing remains important, but sky darkness reigns supreme.

If you live in the city, scout for locations within an hour's drive of home that offer darker skies. Then assemble an equipment kit to make transporting the telescope and accessories easy. The aim is to pack the car



**THE STAR-SPANGLED SKY** is painted red, white, and blue in two summer constellations. *Left*: The 1st-magnitude star Antares (the brightest star in the upper-right quadrant) in Scorpius shines orange. *Right*: The zero-magnitude star Vega (upper right corner) in Lyra blazes bluish-white. LEFT: LUKE DODD / RIGHT: GUY BERSON

**THE RING NEBULA,** or M57, in the constellation Lyra (best seen in the Northern Hemisphere's summer) formed when a dying star shed its outer layers. This 40-minute exposure was taken with an 8-inch Celestron telescope. GERALD RHEMANN

**THE WHIRLPOOL GALAXY** (also known as M51) in the constellation Canes Venatici is a favorite deep-sky target at star parties. This 8th-magnitude face-on spiral was imaged with an SBIG ST10E CCD camera attached to a 7-inch f/9 refractor from Astro-Physics. STEVE MANDEL

**THE ORION NEBULA,** or M42, is a stellar nursery near the middle sword star in the constellation Orion. This composite of two 30-minute exposures was taken with a 12.5-inch f/5 reflector. B. FRANK HINSON AND J. STEVE FOSTER

and go in 10 minutes or less. If it takes much longer, chances are you won't make the trip very often.

Exploring the stellar realm, you soon discover stars have colors, often with beautiful contrasts. If Orion is visible, compare coppery Betelgeuse with blue-white Rigel, which is more than three times hotter. In summer, contrast reddish Antares in Scorpius with white Vega in Lyra, a star more than 2.5 times hotter.

Stars often come in pairs or triplets, but it usually takes high magnification to split them visibly. Attractive summertime examples include Albireo (Beta [β] Cygni) and Epsilon (ε) Lyrae, the so-called Double-Double. In winter, look for the multiple star Theta (θ) Orionis, called the Trapezium, deep in the heart of the Orion Nebula.

Some stars gather into groups, such as the famed Pleiades and Hyades open clusters seen in winter. (Both look best in binoculars, by the way.) Other pretty, telescopic clusters include M41, just 5° south of Sirius in Canis Major (in winter), and globular cluster M13 in Hercules (in spring). Scanning at low magnification through Sagittarius (in summer) will show so many open and globular clusters that you'll lose count.

In Sagittarius, you'll also see something else — stellar birthplaces, clouds of hydrogen and silicate dust called nebulae. They're easiest to spot within our own galaxy, so look for them along the Milky Way (the bright band of light marking the plane of our galaxy's disk) and its neighboring constellations.

One of the sky's most beautiful stellar nurseries is the Orion Nebula. Telescopes of any size show this gas cloud as a glowing cavern lit softly by stars. The bigger the scope, the more stars you see and the richer the sight. In summer, Sagittarius contains many nebulae where stars and gas mingle. A strip of dark dust bisects the Lagoon Nebula, while dust lanes divide the nearby Trifid Nebula into three parts.

Another class of nebulae is the misnamed "planetary" nebulae, so called because 200 years ago William Herschel fancied the nebulae looked like Uranus, which he discovered. These clouds mark where an aging star has thrown off its gaseous outer layers. An outstanding example is the Ring Nebula in Lyra (in summer).

## Into infinity

Our home, the Milky Way, is a spiral galaxy of such immense proportions that light takes 100,000 years to cross its diameter. Yet galaxies are just the building blocks of larger structures. Spiral galaxies, which make up almost 80 percent of all galaxies, are lovely in any telescope. Telescopes pointed at the Andromeda Galaxy (in autumn) reveal ghostly arms wrapped snugly around a bright central nucleus. The Whirlpool Galaxy (in spring) lies tucked under the handle of the Big Dipper. We see this spiral face-on, with one arm pulled out by the passage of another galaxy nearby.

For backyard skywatchers, the richest collection of all kinds of galaxies lies in the spring constellations Virgo and Coma Berenices. The Coma-Virgo galaxy cluster lies about 65 million light-years away; it contains dozens of galaxies within reach of a backyard telescope. Look for it just east of Denebola (Beta [β]) in the tail of Leo.

One last stop awaits every backyard astronomer at the end of an observing run. Step back from the telescope and look at the sky as you did when you started the night. This time, focus your gaze between the stars. Look for a patch of darkness containing nothing visible.

That blackness represents the universe better than anything a telescope can show. As cosmologists have discovered, less than 5 percent of the universe is visible matter. The rest consists of dark matter, whose nature is unknown, plus a much larger proportion of something called "dark energy" that scientists have only just begun to probe.

Tonight, your first telescopic explorations have taken you to the bounds of the universe. So it can go every night if you turn the telescope toward the sky.

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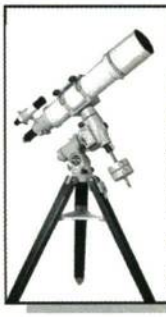

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MARTIN RATCLIFFE is former president of the International Planetarium Society. He writes and observes from Wichita, Kansas, and is Director of Theaters and Media Services at Exploration Place.

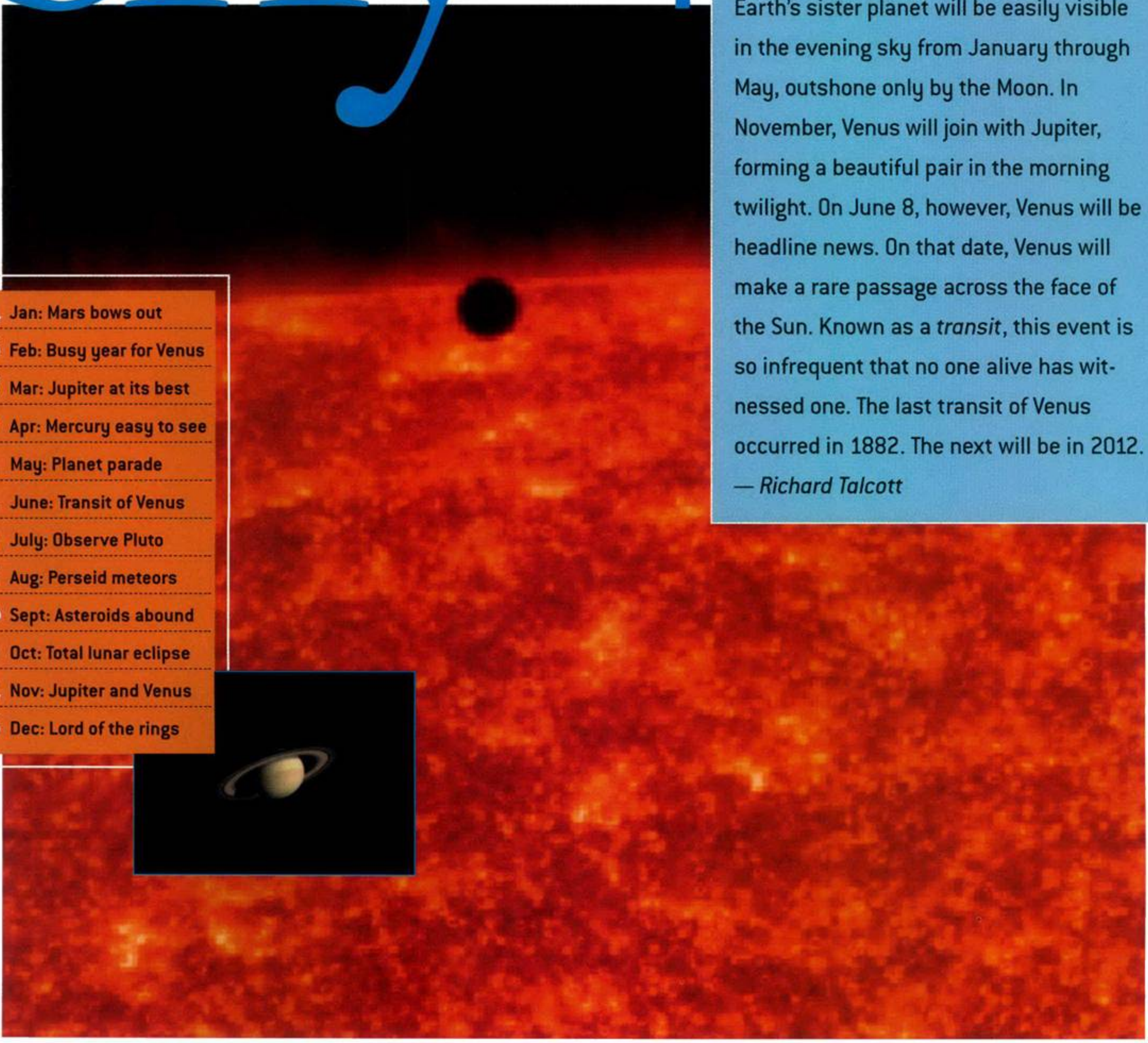
# sky guide :04

THE SUN

## Venus crosses the face of the Sun in June.

Venus will play a prominent role in 2004. Earth's sister planet will be easily visible in the evening sky from January through May, outshone only by the Moon. In November, Venus will join with Jupiter, forming a beautiful pair in the morning twilight. On June 8, however, Venus will be headline news. On that date, Venus will make a rare passage across the face of the Sun. Known as a *transit*, this event is so infrequent that no one alive has witnessed one. The last transit of Venus occurred in 1882. The next will be in 2012.
— *Richard Talcott*

44 **Jan: Mars bows out**
46 **Feb: Busy year for Venus**
48 **Mar: Jupiter at its best**
50 **Apr: Mercury easy to see**
52 **May: Planet parade**
54 **June: Transit of Venus**
56 **July: Observe Pluto**
58 **Aug: Perseid meteors**
60 **Sept: Asteroids abound**
62 **Oct: Total lunar eclipse**
64 **Nov: Jupiter and Venus**
66 **Dec: Lord of the rings**



*Inset,* **SATURN** will be a noteworthy object late in the year. NASA/JPL/SOUTHWEST RESEARCH INSTITUTE

*Above,* **THE 2003 TRANSIT OF MERCURY** seen on May 7 only served to whet our appetite for a rare Venus transit this June. NASA/TRACE

# jan:04

To many people, the best views of Mars ended last August, when the Red Planet was in opposition, closest to Earth, and bigger and brighter than at any time in the last 50,000 years. Big mistake. Although Mars has faded significantly since last summer, it remains a bright object throughout early 2004 and makes a tempting target in backyard telescopes.

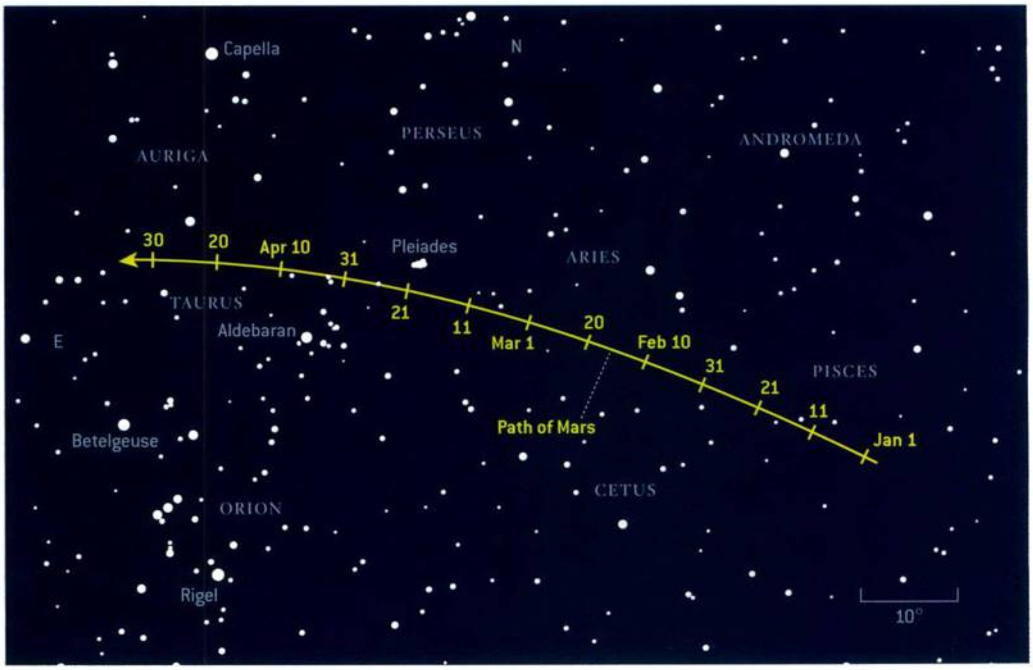
## Mars bows out

The spectacular appearance of Mars in the evening sky last summer attracted millions of skywatchers. Throughout the last four months of 2003, Mars appeared as a bright evening object. Never before have so many observers managed such good views of the Red Planet. Its brilliant orange-hued glow even outshone Jupiter at its best.

By the beginning of 2004, Mars has receded considerably from Earth yet remains a bright object as it wanders in front of the stars of Pisces the Fish. On January 1, Mars shines at magnitude 0.2, and it fades to magnitude 1.0 by February 21. Through a telescope, the apparent size of Mars has shrunk to 8", just one-third of its glory last summer. At this size, it's a tricky object for small telescopes, but scopes with apertures in excess of 10 inches can still show its surface features and seasonal changes.

Notice how long Mars lingers in the evening sky. Its orbital speed around the Sun is not greatly different from ours, so Mars appears to "keep up" as the Sun marches along the ecliptic. Mars maintains a wide separation between itself and the star to which it is forever gravitationally bound, and it takes until late summer before finally succumbing to the Sun's presence.

Along the way, Mars makes some notable conjunctions. Watch after sunset on January 27 for the First Quarter Moon lying 3° south of Mars. By March 19, when it has faded to magnitude 1.3, Mars passes less than 3° south of the Pleiades star cluster in Taurus the Bull. On the same night, Venus, easily outshining the Red



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EST:

4 Quadrantid meteor shower peaks

6 The Moon passes 5° north of Saturn, 7 P.M.

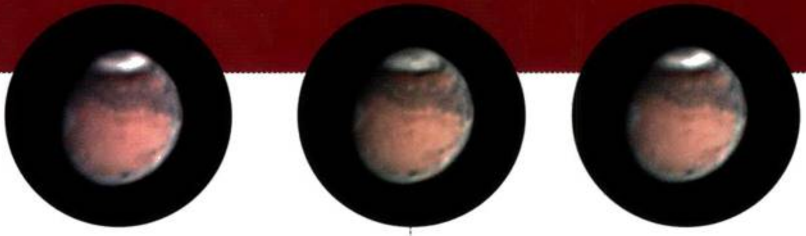
9 Asteroid Ceres is at opposition, 9 A.M.

12 The Moon passes 3° north of Jupiter, 6 A.M.

14 Venus passes 0.9° south of Uranus, 8 P.M.

17 Mercury is at greatest western elongation (24°), 5 A.M.

**MARS WRAPS UP** its great apparition in 2004, remaining visible until summer. NASA AND THE HUBBLE HERITAGE TEAM (STScI/AURA)



**MARS ROTATES SLIGHTLY** over 31 minutes, imaged June 5, 2003, when Mars was a little bit larger than it will be at the beginning of this year. DONALD C. PARKER

Planet, lies 14° to the lower right of Mars. A fine opportunity for wide-angle photography occurs on March 25. On this evening, you'll find a slim crescent Moon only two Moon-widths from Mars.

Venus and Mars continue a gentle parade across Taurus, and the following month, on the American evening of April 23, an even skinnier crescent Moon lies 3° above Mars with Venus standing nearby at the eastern end of Taurus.

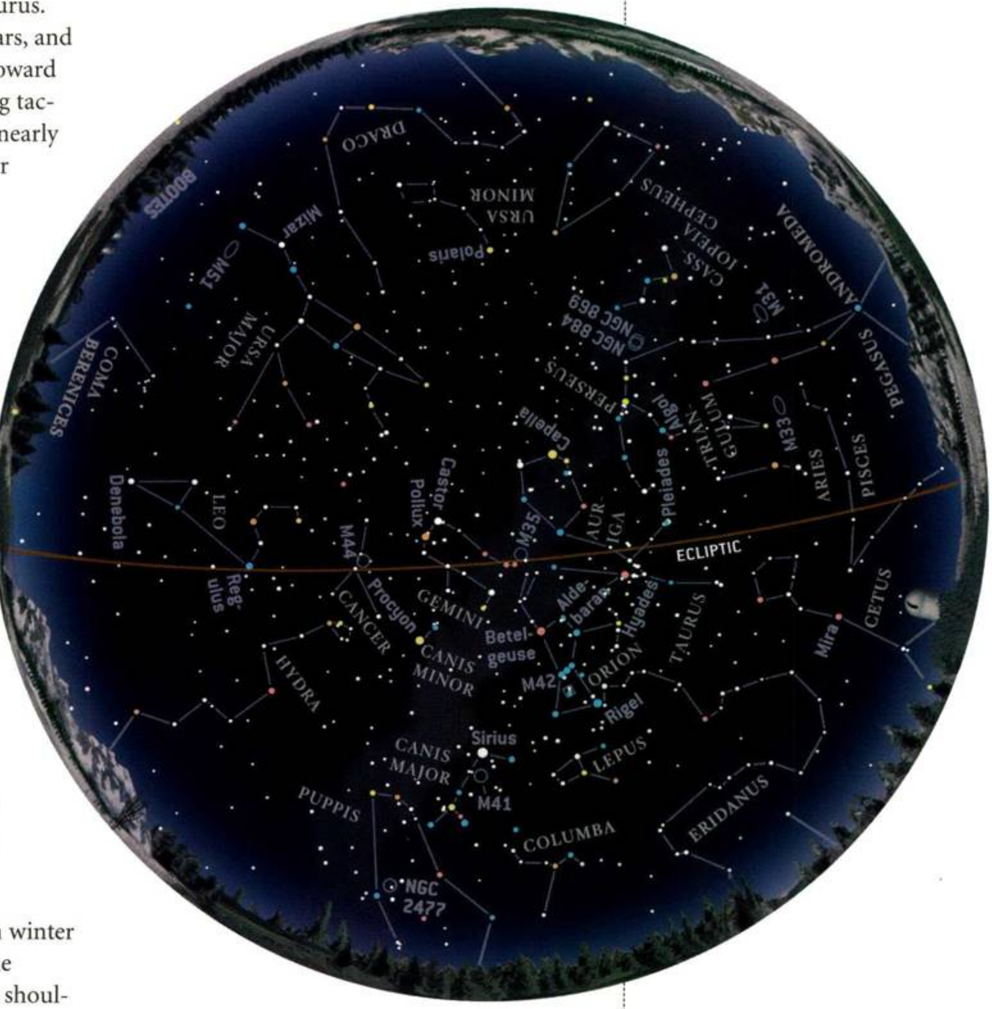
Venus never quite catches up with Mars, and during May, Venus appears to fall back toward the Sun while Mars continues its delaying tactics. Although the 2003/04 apparition is nearly over, observers will be talking about it for years to come.

## Explore the winter sky

One of the major signposts of the entire sky, Orion the Hunter dominates the winter sky. Three closely spaced, 2nd-magnitude stars in a straight line form the unmistakable belt of Orion. Extending the imaginary line joining these stars to the upper right leads to Taurus the Bull and its orangish 1st-magnitude star, Aldebaran. Reverse the direction of your gaze to the belt's lower left and you cannot miss Sirius the Dog Star — the brightest in all the heavens at magnitude –1.5.

Now move perpendicular to the belt from its westernmost star to find Betelgeuse, the red supergiant star at the upper left of Orion. Continuing this line brings you to a pair of stars, Castor and Pollux, in Gemini the Twins.

Above Orion, and nearly overhead on winter evenings, is brilliant Capella in Auriga the Charioteer. Extending a line through the shoulders of Orion to the east leads you to Procyon in Canis Minor. Once you have these principal stars mastered, using the chart to discover the fainter constellations will be a lot easier. Take your time, and enjoy the journey.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Polaris
BOOTES
Mizar
M51
URSA MAJOR
COMA BERENICES
CEPHEUS
CASSIOPEIA
ANDROMEDA
M31
NGC 869
NGC 884
PERSEUS
Algol
TRIANGULUM
M33
PEGASUS
PISCES
ARIES
Capella
Castor
Pollux
M35
AURIGA
Pleiades
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Regulus
M44
CANCER
Procyon
GEMINI
Betelgeuse
Aldebaran
Hyades
TAURUS
ECLIPTIC
CETUS
Mira
CANIS MINOR
M42
ORION
Rigel
HYDRA
Sirius
LEPUS
ERIDANUS
CANIS MAJOR
M41
PUPPIS
COLUMBA
NGC 2477

19 The Moon passes 5° south of Mercury, 10 P.M.

23 The Moon passes 4° south of Uranus, 4 P.M.

24 The Moon passes 4° south of Venus, 11 P.M.

27 The Moon passes 3° south of Mars, 10 P.M.

Events in red are ones you won't want to miss.

All times in the calendar are eastern time.

# feb:04

# A busy year for Venus

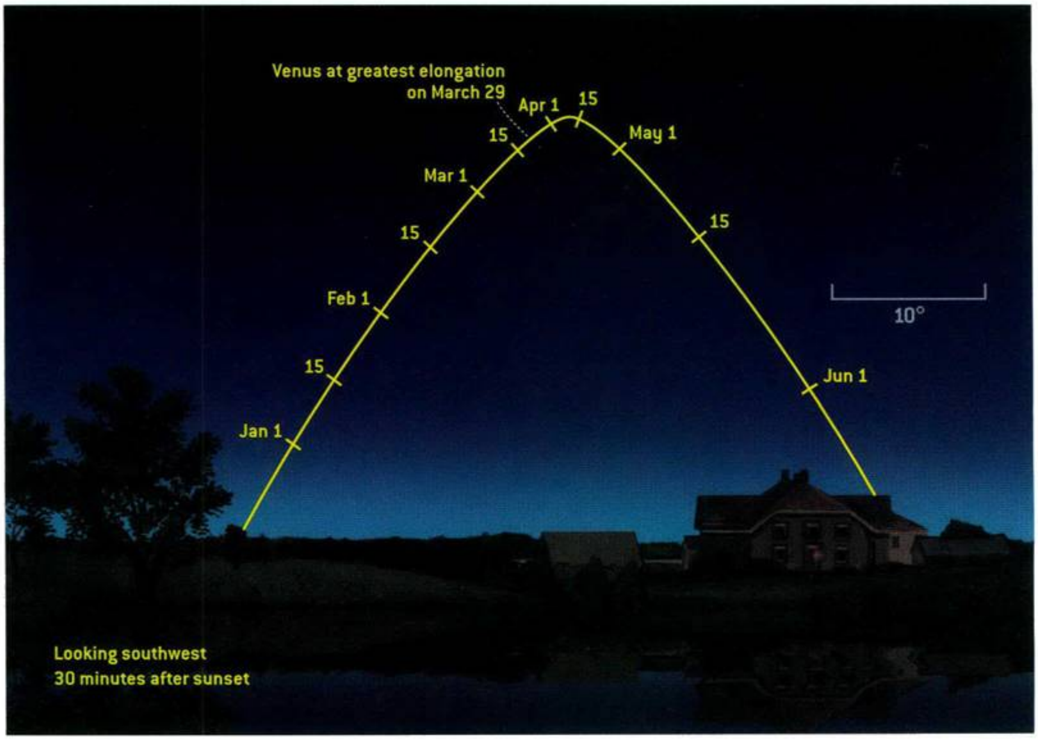
This year may rank as the most momentous for Venus in more than 100 years. Two first-rate apparitions will occur: During the first five months of 2004, it shines brilliantly in the evening sky; in the second half of the year, Venus performs equally well before dawn. But the highlight of the year comes in between, when it transits the face of the Sun on June 8.

Venus can be seen in the evening hours during the first half of 2004, and following inferior conjunction on June 8 when it performs a rare transit of the Sun, it passes into the morning sky for the remainder of the year.

Venus shines dazzlingly bright and high above the western horizon from January onward. At the beginning of the year, it shines at magnitude –4.0. Through a telescope, Venus reveals a gibbous phase that slowly diminishes as the months pass. As the phase shrinks, the apparent size of Venus's disk actually increases. On January 1, for example, Venus spans a diminutive 13", and 83 percent of its disk appears illuminated. By January 24, when a slender crescent Moon hangs 4° southeast of Venus, the planet's phase has shrunk to 77 percent lit and its apparent size has grown by 1".

Leaping forward to the end of February (the 29th because 2004 is a leap year), Venus now spans 18", and its phase has waned noticeably to 65 percent lit. The Moon skims past Venus on February 23, this time passing 3° south of the planet among the stars of Pisces the Fish. At sunset, Venus lies high and looks prominent in the west-southwest and sets more than three hours after the Sun.

On March 29, Venus stands 46° east of the Sun, its greatest elongation from our star. It appears just about half-lit, but it's a fun



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**EST:**

2 Neptune is in conjunction with the Sun, 4 A.M.

The Moon passes 4° north of Saturn, 11 P.M.

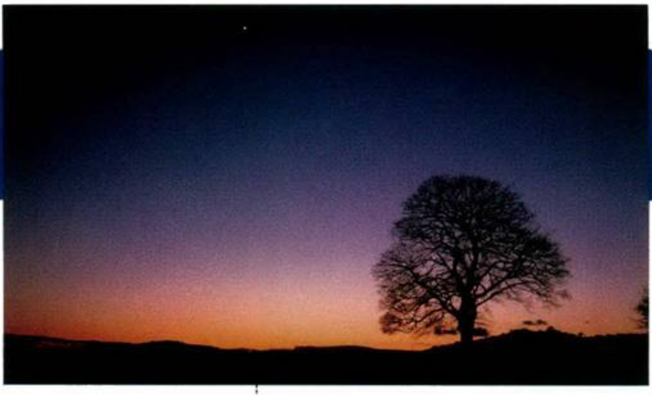
8 The Moon passes 3° north of Jupiter, 9 A.M.

15 Mercury passes 2° south of Neptune, 4 A.M.

18 The Moon passes 5° south of Neptune, 8 P.M.

21 Uranus is in conjunction with the Sun, 9 P.M.

**PEERING BENEATH THICK CLOUDS,** the Magellan radar mapper captured the surface of Venus. NASA/JPL



**VENUS SHINES BRILLIANTLY** in the evening twilight of February 1993. The brightest point of light in the sky, Venus is unmistakable whenever it's out. ANDREW COTTAM

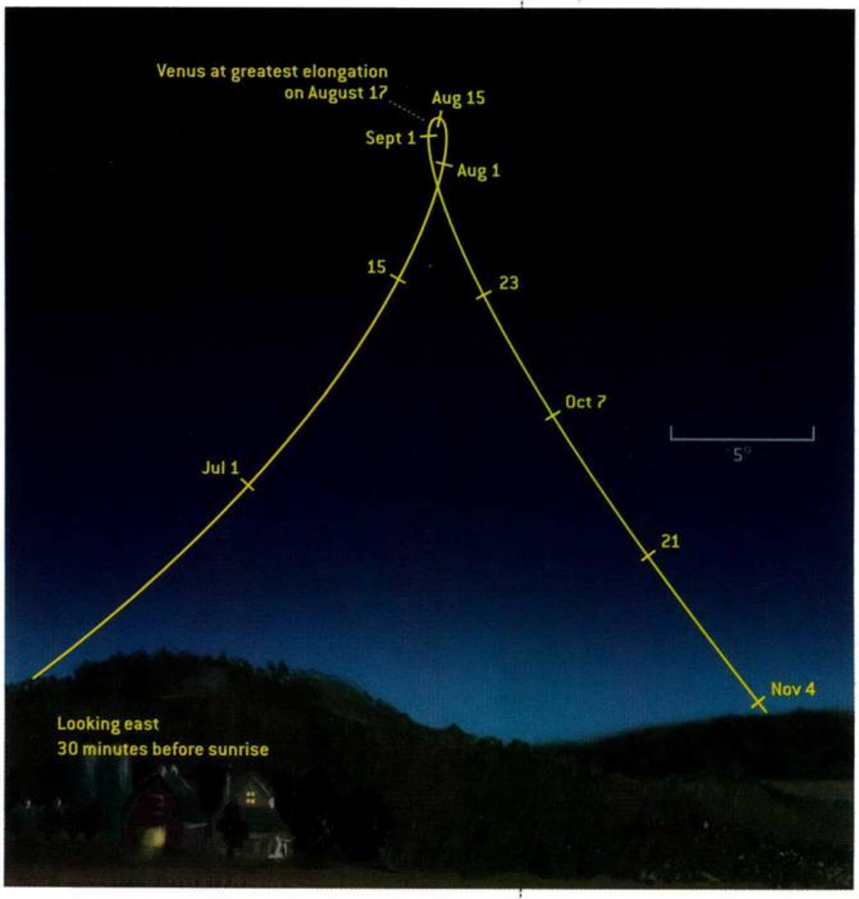
challenge to try and pin down the date when the planet is exactly half-illuminated.

In early April, Venus lies close to the Pleiades star cluster (M45). This makes for a fine photo opportunity because Mars stands 10° away at magnitude 1.4 (similar in brightness to Aldebaran in Taurus the Bull). Watch for the conjunction of the crescent Moon, Mars, and Venus on April 23. Mars and Venus never get closer than 5° apart because Venus starts to swing back toward the Sun at an increasing rate until it reaches inferior conjunction on June 8. Venus's phase shrinks rapidly during April and May while its apparent size swells. In early May, Venus spans more than 40", and its phase shrinks to 25 percent lit, but it shines at its greatest brilliancy, magnitude –4.5.

During the inferior conjunction on June 8, Venus transits (or crosses) the face of the Sun for the first time in more than a century (see June for transit details).

Venus reappears in the morning sky during July. On July 4, it lies 1° north of Aldebaran. Venus crosses Taurus and moves into Gemini in August, reaching greatest western elongation on August 17 when it stands 46° from the Sun. September opens to find Venus standing 1° south of Saturn. On this date, both planets can be seen in a rich-field telescope. The view of Saturn and its rings with a 58-percent-illuminated Venus will be a sight to remember.

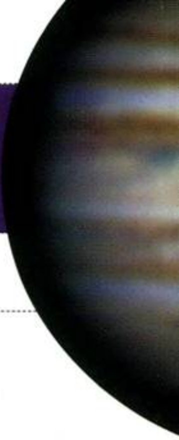
Watch for the appearance of Mercury near the star Regulus in Leo the Lion during the first week of September with Venus standing watch high above in the east. Mercury repeats its appearance in December, this time meeting Venus in the early dawn sky. On December 29, Mercury lies 1.2° north of Venus among the stars of Ophiuchus. As you can see, Venus puts on quite a show in 2004, exhibiting its full range of brightness, phases, a rare transit, and several conjunctions with the Moon and other planets.



23 The Moon passes 3° south of Venus, 2 P.M.

25 The Moon passes 0.9° south of Mars, 9 P.M.

# mar:04



## Jupiter at its best

Big, bright, and detailed — Jupiter has it all. And this year it struts its stuff exceptionally well. When it reaches opposition on March 4, it shines brighter than any other object in the night sky except the Moon and Venus. A small telescope will reveal a wealth of detail in the planet's roiling atmosphere as well as the never-ending ballet of its four bright Galilean moons.

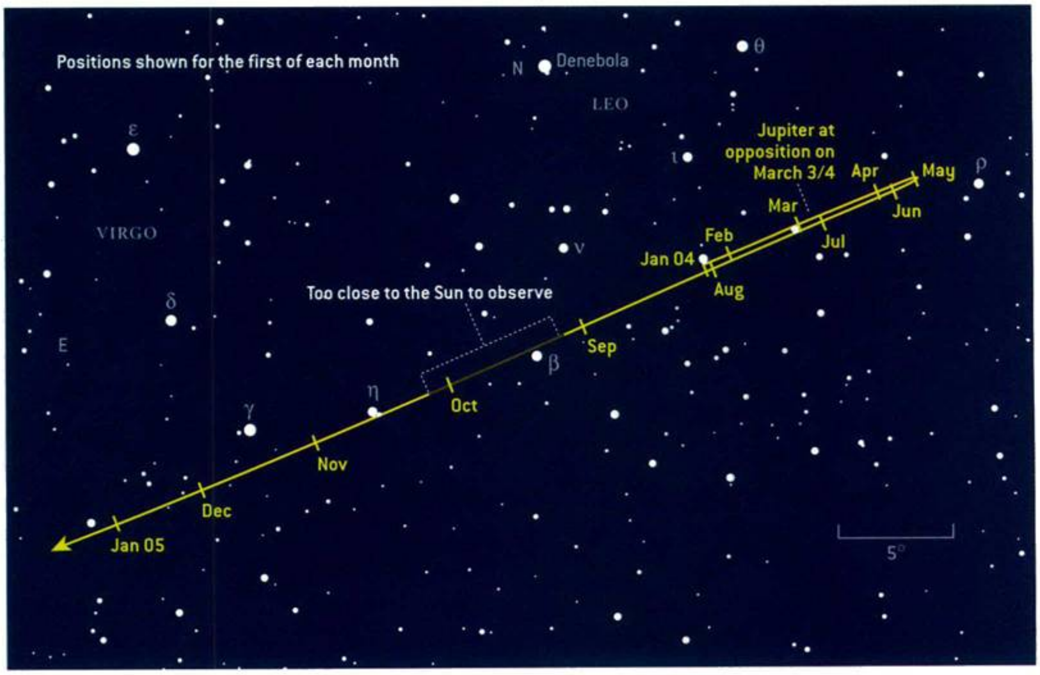
Jupiter is big, turns fast on its axis, and constantly presents new features to watch. At first glance, we see Jupiter as a very bright "star" among the fainter starry background of Leo the Lion. Only a telescope reveals the drama in Jupiter's atmosphere — and best of all, a 2.4-inch or larger scope shows all the major activity.

Jupiter reaches opposition on March 3, when it lies opposite the Sun and remains visible all night. Afterward, it becomes an evening object. The planet lies in southeastern Leo in March. Jupiter continues moving gradually westward relative to the stars until May, when it stands less than 10° from Regulus, Leo's brightest star.

At opposition, Jupiter shines at magnitude –2.5, becoming the brightest object in the sky other than the Moon and Venus. Three nights past opposition, on March 6, the Full Moon lies less than 7° northwest of Jupiter.

It would take 12 Earths to equal the girth of Jupiter. Yet even at opposition, when it lies closest to Earth, Jupiter stands more than 410 million miles away, so far that light requires 36 minutes to cross the expanse. At this distance, Jupiter's giant orb spans about 1/80°, or 44".

Regular observers of Jupiter who live in the Northern Hemisphere will notice that each opposition since 2001 occurred at a lower altitude. This trend continues for the next few years. Each of the next six oppositions after 2004 finds Jupiter south of the celestial equator, placing it at a lower altitude than in the previous six years. Consequently, views of Jupiter appear through ever-thicker wedges of Earth's atmosphere.


Positions shown for the first of each month
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Jupiter at opposition on March 3/4
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| ◑ | 29 | 30 | 31 | | | |

EST:

1 The Moon passes 5° north of Saturn, 5 A.M.

3 Mercury is in superior conjunction, 9 P.M.

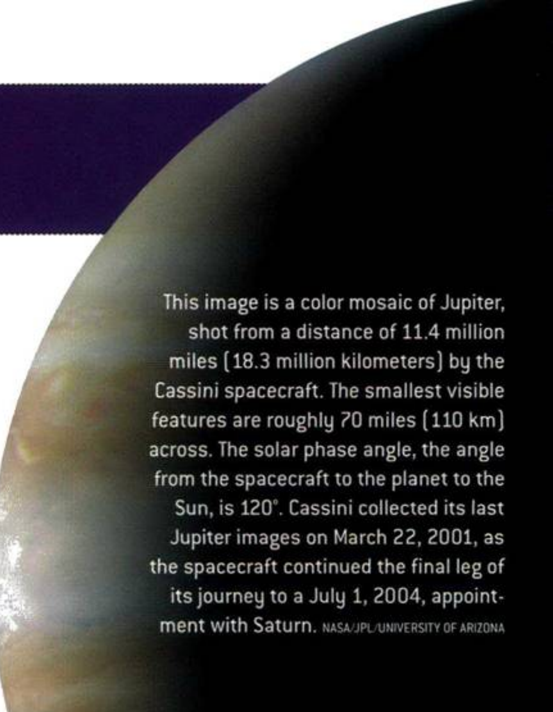
3 Jupiter is at opposition, midnight

6 The Moon passes 3° north of Jupiter, 11 A.M.

17 The Moon passes 5° south of Neptune, 4 A.M.

18 The Moon passes 4° south of Uranus, 3 P.M.

**JUPITER GLOWS BRIGHTLY** in the evening sky from March through August. SUBARU TELESCOPE, NAOJ



This image is a color mosaic of Jupiter, shot from a distance of 11.4 million miles (18.3 million kilometers) by the Cassini spacecraft. The smallest visible features are roughly 70 miles (110 km) across. The solar phase angle, the angle from the spacecraft to the planet to the Sun, is 120°. Cassini collected its last Jupiter images on March 22, 2001, as the spacecraft continued the final leg of its journey to a July 1, 2004, appointment with Saturn. NASA/JPL/UNIVERSITY OF ARIZONA

The four major satellites of Jupiter can be viewed easily in small scopes and often are seen even in tripod-mounted binoculars. Io, Europa, Ganymede, and Callisto orbit Jupiter in periods ranging from 2 to 16 days. They provide a "mini-solar system" we can observe from afar.

Small scopes also will reveal the two major equatorial belts in the jovian atmosphere. Lying on either side of the planet's equator, the dark equatorial belts and the lighter areas neighboring them are the regions of most activity visible in amateur scopes.

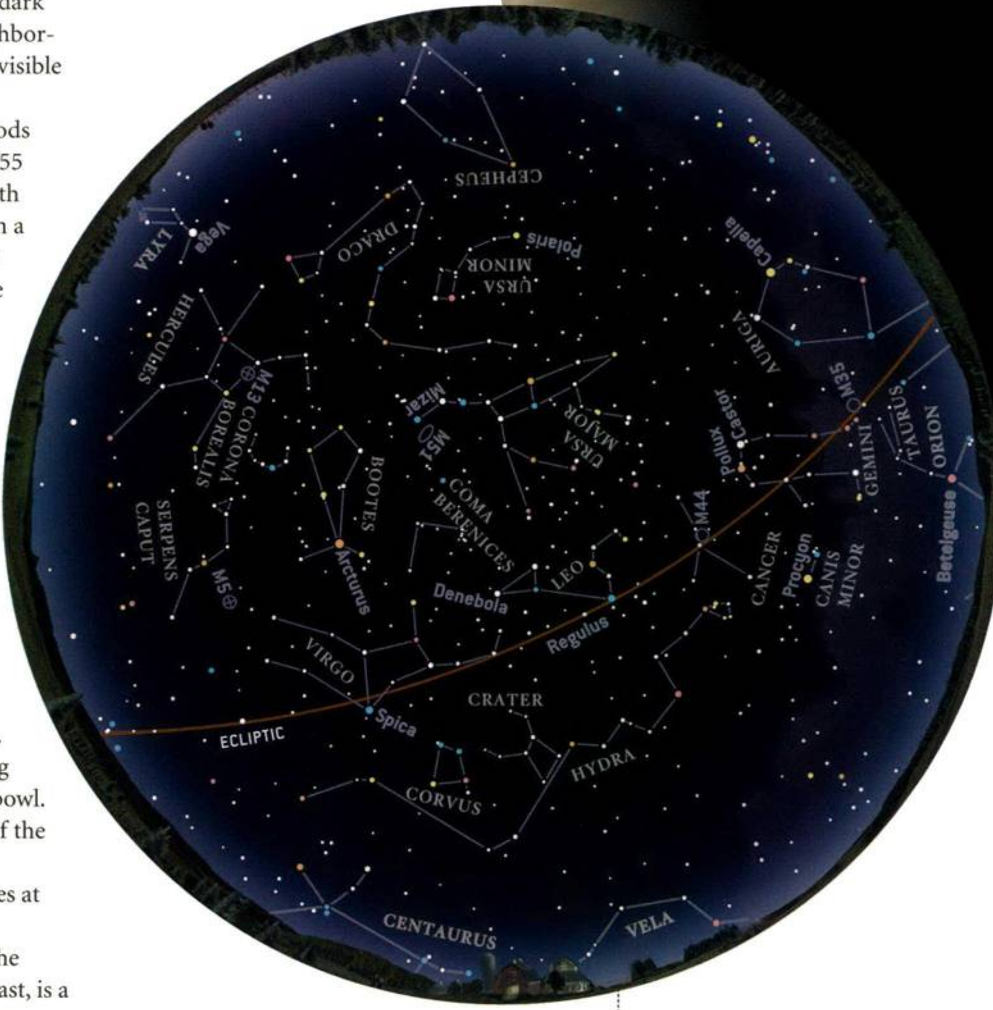
Features rotate with the planet in periods between 9 hours 50 minutes and 9 hours 55 minutes, depending on their location. With 12 hours of darkness in March, more than a full rotation of Jupiter can be seen in one night. Once you become familiar with the atmospheric features, you'll want to track them night after night to see how they change.

## Explore the spring sky

The Big Dipper swings high overhead on spring evenings, a convenient signpost in the sky. Follow the arc of stars forming the handle of the Dipper away from the bowl and you will find brilliant Arcturus. This orange star dominates the spring sky in the kite-shaped constellation Boötes the Herdsman. To the west of Boötes lies Leo. Find its brightest star, Regulus, by heading south from the end stars in the Dipper's bowl.

To the southeast of Leo is the "realm of the galaxies" and the constellation Virgo the Maiden. Virgo's brightest star, Spica, shines at magnitude 1.0.

Midway between Arcturus and Vega, the bright "summer" star rising in the northeast, is a region where no star shines brighter than 2nd magnitude. A semicircle of stars represents Corona Borealis, and adjacent to it is a large region that houses Hercules, the fifth-biggest constellation in the sky. It's here we find the northern sky's brightest globular cluster, M13. A naked-eye object from a dark site, it is spectacular when viewed through a telescope.


CEPHEUS
DRACO
Polaris
URSA MINOR
LYRA
Vega
HERCULES
M13
CORONA BOREALIS
SERPENS CAPUT
M5
BOOTES
Arcturus
Mizar
M51
COMA BERENICES
URSA MAJOR
Denebola
LEO
Regulus
VIRGO
Spica
ECLIPTIC
CRATER
CORVUS
HYDRA
CENTAURUS
VELA
Capella
AURIGA
Castor
Pollux
M44
CANCER
Procyon
CANIS MINOR
GEMINI
M35
TAURUS
ORION
Betelgeuse

20 Equinox (northern spring/southern autumn begins), 2 A.M.

21 The Moon passes 4° south of Mercury, midnight

24 The Moon passes 2° south of Venus, 4 P.M.

25 The Moon passes 0.8° north of Mars, 7 P.M.

28 The Moon passes 5° north of Saturn, 2 P.M.

29 Mercury is at greatest eastern elongation (19°), 7 A.M.

29 Venus is at greatest eastern elongation (46°), noon

# apr :04

# Mercury's year of excellence

The most elusive bright planet, Mercury, normally presents a viewing challenge. In a continual game of cat-and-mouse with its bigger, brighter cousin, the Sun, the innermost planet rarely pulls far enough away to offer a good view. Yet 2004 presents three good opportunities. Evening observers should target late March and early April for a good look, while early risers should wait until September or late December.

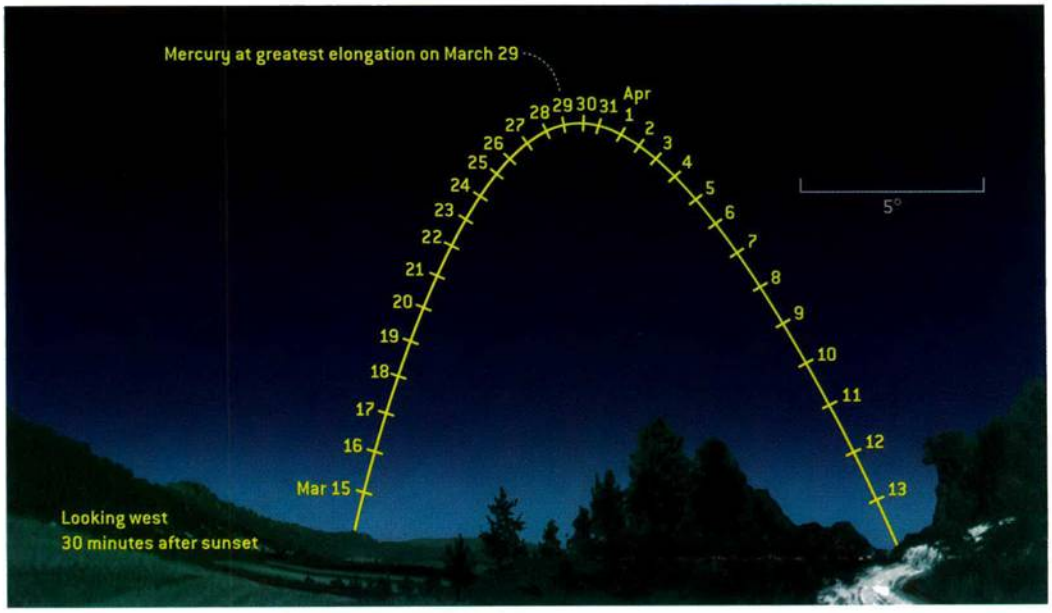
At its best, Mercury, the innermost planet in the solar system, never strays farther than 27° from the Sun. And typically, this value is much less. Consequently, Mercury always appears to hug the horizon. It appears low in the east before sunrise or low in the west after sunset, which is not surprising when we consider Mercury's 36-million-mile distance from the Sun. Combine that with Mercury's quick 88-day orbital period, and even though the planet may be well placed, such fine circumstances last only a week or two.

Yet choose the right moment and Mercury appears obvious. Conditions are best at latitudes within 45° of the equator. At such latitudes, at least once a year, the ecliptic — the apparent path of the Sun across the sky that the planets also follow closely — makes a steep angle to the horizon. If at this time Mercury is also fairly far from the Sun, it will be reasonably high in the sky.

From the Northern Hemisphere, such occasions occur in the evenings between March 14 and April 9 and in the mornings between September 1 and September 25 and from December 16 to December 31.

At the start of its stellar evening apparition in mid-March, Mercury appears low in the west about half an hour after sunset. By March 20, the planet appears in dark twilight and shines at magnitude –1.1. Through a telescope, it appears 6" across and 75 percent illuminated. On March 21 and 22, a young crescent Moon hangs nearby, aiding in Mercury's identification.

On March 29, when it stands 19° east of the Sun, Mercury lies below the 2nd-magnitude star Hamal, the brightest star in Aries the Ram. Venus dominates the evening sky above Mercury, shining brilliantly not far from the Pleiades. On April 1, Mercury shines at magnitude 0.5 and its



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| 18 | ○ | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | ◑ | 28 | 29 | 30 | |

EDT:

2 The Moon passes 3° north of Jupiter, 2 P.M. EST

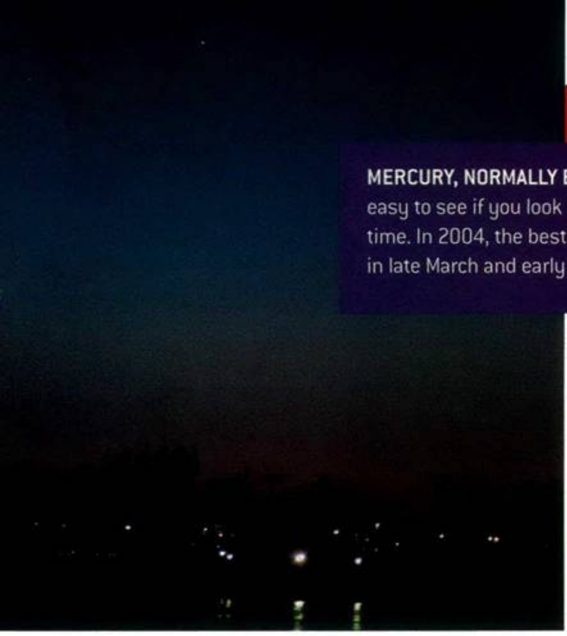
7 Mars passes 7° north of Aldebaran, 1 A.M.

13 The Moon passes 5° south of Neptune, noon

14 The Moon passes 4° south of Uranus, midnight

16 Venus passes 10° north of Aldebaran, 6 A.M.

Mercury is in inferior conjunction, 9 P.M.



**MERCURY, NORMALLY ELUSIVE,** is actually easy to see if you look for it at the right time. In 2004, the best evening times are in late March and early April. GEORGE LIVADARAS

### /// WHEN TO SEE MERCURY IN 2004

**EVENING**

| *Greatest elongation* | *Visible from* | *Peak altitude* |
|---|---|---|
| Mar 29 | Mar 14 to Apr 9 | 12° |
| July 26 | June 26 to Aug 17 | 8° |
| Nov 20 | Oct 20 to Dec 4 | 6° |

**MORNING**

| *Greatest elongation* | *Visible from* | *Peak altitude* |
|---|---|---|
| Jan 17 | Jan 2 to Feb 21 | 11° |
| May 14 | Apr 26 to June 11 | 5° |
| Sept 9 | Sept 1 to Sept 25 | 11° |
| Dec 29 | Dec 16 to Dec 31 | 12° |

8"-diameter disk appears one-third illuminated. In the following week, the twilight glow creeps up quickly and swallows it.

A superb sight awaits observers during Mercury's September morning apparition. At greatest western elongation on September 9, Mercury and Leo's brightest star, Regulus, rise together. The pair appear closest on the 10th when they lie 0.2° (less than half the Moon's diameter) apart. Both objects appear in the same low-power telescopic field of view. Mercury shines significantly brighter at magnitude –0.3, while Regulus comes in at magnitude 1.3.

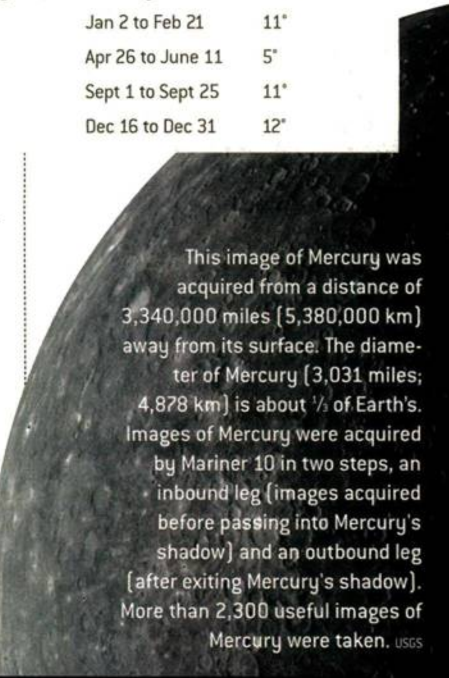
This apparition begins with Mercury rising out of the pre-dawn glow in early September. Through a scope, watch Mercury's crescent fatten quickly. On September 5, it shows a 27-percent-lit phase. That swells to 50 percent by the 10th. A waning crescent Moon stands 7° above Mercury on the 12th.

A week later, Mercury brightens to magnitude –1.0 and shows a three-quarters-lit gibbous phase. Venus and Saturn stand above Mercury in the morning sky. Mercury continues to brighten but quickly becomes lost in the pre-dawn glow in late September.

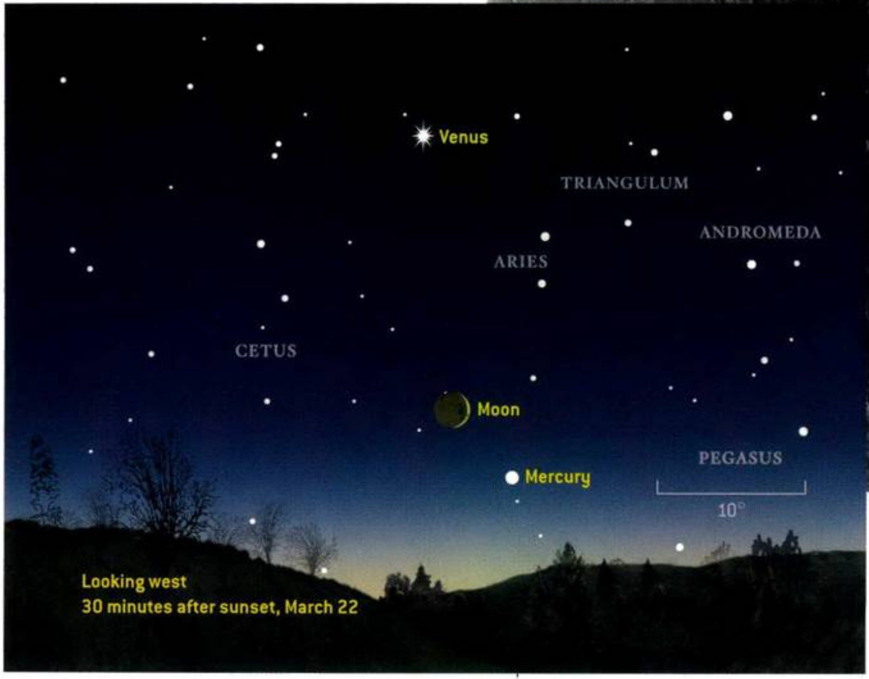
A year-end view of Mercury occurs in late December, almost repeating September's morning view except this time the planet lies among the stars of Scorpius and Ophiuchus. The additions of Venus and Mars clustered in the morning make a great way to close out 2004. On December 20, look for –3.9-magnitude Venus rising in the southeast at approximately 5:45 A.M. local time. Mercury, dimmer than its sky-mate at magnitude 0.3, rises 22 minutes later to the lower left of Venus.

On December 29, Mercury lies 1.2° north of Venus. Both planets lie in Ophiuchus, the often-overlooked 13th constellation along the ecliptic. Mercury stands 22° from the Sun on this day. Mars lies 13° farther west and Antares lies 8° below the Red Planet, peeking above the southeastern horizon just before the brightening dawn steals its glow. Look for them together around 6:30 A.M. local time.

Venus and Mercury seem to waltz together along the ecliptic, their apparent separation shrinking each day. In early 2005, the waning crescent Moon wanders onto the scene. On January 8, 2005, the slender crescent lies 8° to the right of Venus and Mercury, which are separated by just 0.8°.



This image of Mercury was acquired from a distance of 3,340,000 miles (5,380,000 km) away from its surface. The diameter of Mercury (3,031 miles; 4,878 km) is about ⅓ of Earth's. Images of Mercury were acquired by Mariner 10 in two steps, an inbound leg (images acquired before passing into Mercury's shadow) and an outbound leg (after exiting Mercury's shadow). More than 2,300 useful images of Mercury were taken. USGS



Looking west
30 minutes after sunset, March 22

19 Partial solar eclipse, 9 A.M.

21 Lyrid meteor shower peaks

23 The Moon passes 1.5° south of Venus, 6 A.M.

23 The Moon passes 2° north of Mars, 5 P.M.

25 The Moon passes 5° north of Saturn, 2 A.M.

29 The Moon passes 4° north of Jupiter, 10 P.M.

# may:04

## A parade of five evening planets

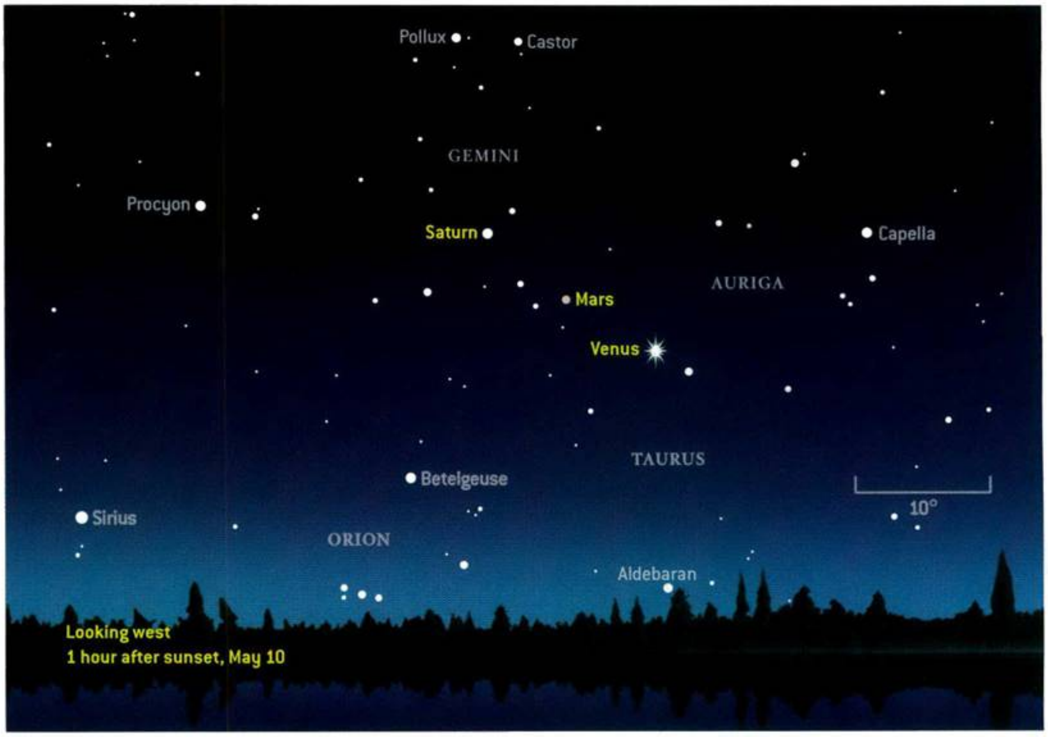
Spring 2004 provides a superb chance to see all five planets known in antiquity. Mercury, Venus, Mars, Jupiter, and Saturn span the evening sky during this season of rebirth. The grand planetary line-up couldn't be timed any better either: It comes on the heels of frigid winter observing, when conditions don't inspire long looks through the eyepiece, and before the too-short nights of summer.

Five major planets span the night sky during April and May. From the western horizon eastward, you'll find Mercury, Venus, Mars, Saturn, and Jupiter. Venus, the brightest, appears first after sunset. Jupiter comes into view next, high in the southeast. Then Mercury peeks out (early April only), followed by Saturn and Mars.

Check the western horizon after sundown on April 2 to catch Mercury shining at magnitude 0.6 in Aries the Ram. Nearly 30° above Mercury lies Venus, and as the sky darkens, you'll find the Pleiades star cluster next to Venus. Mercury disappears from the scene after the first week of April, but for the following two months, Venus, Mars, Saturn, and Jupiter remain in view.

Venus tries to catch up with Mars as the planets pass through the stars of Taurus. On April 22 and 23, less than 6° separate the two, while a waxing crescent Moon joins them nearby. Mars shines at magnitude 1.6, less than 1 percent as bright as Venus, now at magnitude –4.5. Venus, however, begins to fall back toward the Sun and gets no closer to Mars.

Meanwhile, Saturn sits at the feet of Gemini, about 16° above Mars. Saturn shines at magnitude 0.1. By May 10, Mars lies midway between Venus and Saturn, only 8° from both these neighbors. This brilliant planetary line-up, joined by the bright winter stars, presents one of the year's most pleasing sights in the night sky.



**Looking west**
**1 hour after sunset, May 10**

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| 23 | 24 | 25 | 26 | ◑ | 28 | 29 |
| 30 | 31 | | | | | |

EDT:

2 Venus is at greatest brilliancy (magnitude –4.5), 4 A.M.

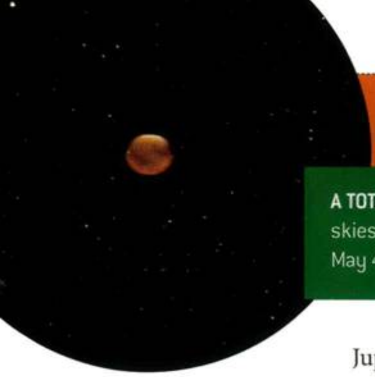
4 Total lunar eclipse, 5 P.M.

4 Eta Aquarid meteor shower peaks

10 The Moon passes 5° south of Neptune, 6 P.M.

12 The Moon passes 4° south of Uranus, 8 A.M.

14 Mercury is at greatest western elongation (26°), 5 P.M.



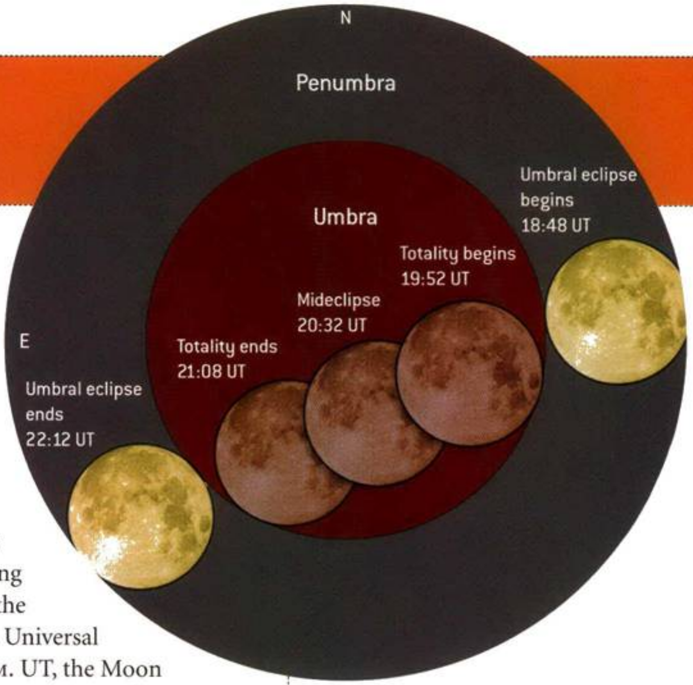
**A TOTAL LUNAR ECLIPSE** will grace the skies above the Eastern Hemisphere on May 4. CRAIG STOTT

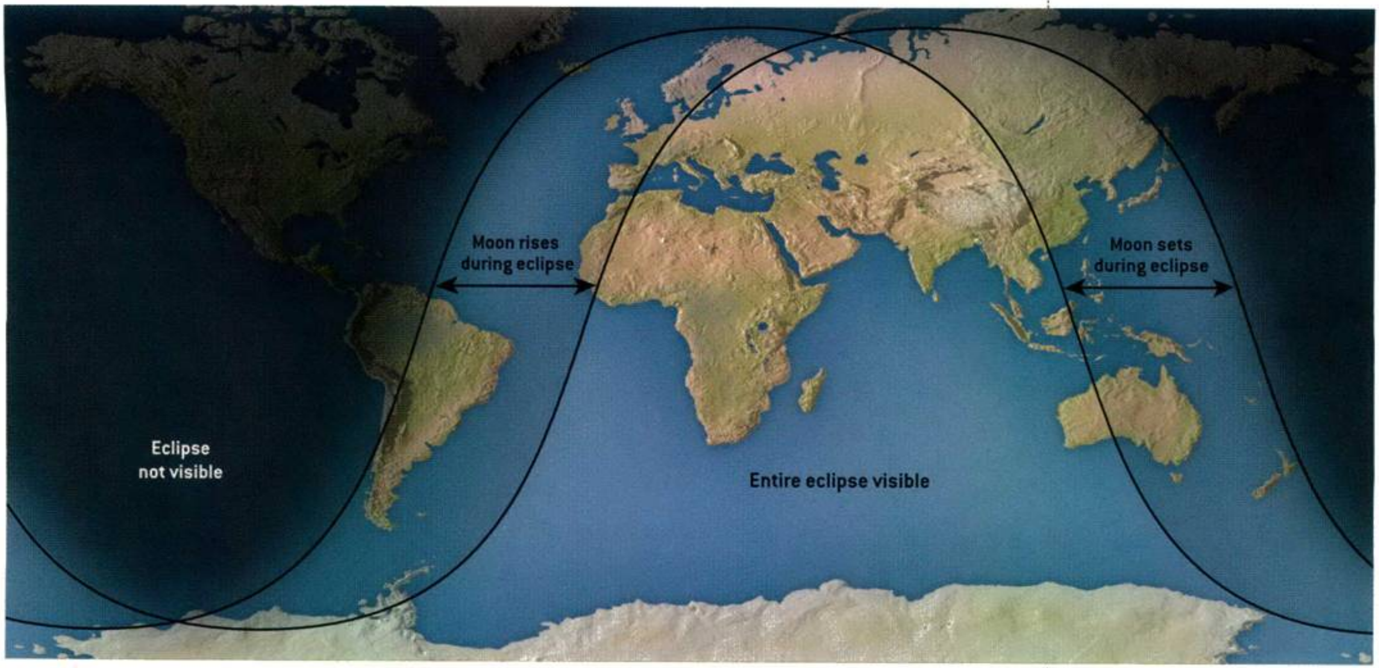
Jupiter lies among the stars of Leo, one-third of the way across the sky from Saturn. It shines at magnitude –2.2 and appears nearly stationary. Mars and Saturn, on the other hand, are about to switch positions on May 21 and 22 as the Moon glides past the pair. On May 24, Mars sits 1.6° north of Saturn. In the days following this conjunction, Mars continues across Gemini. Saturn succumbs slowly to the glare of the Sun, but not before Venus makes its descent into the bright twilight. Venus disappears from view around the end of May, bringing to an end this fine planetary arrangement.

## The Moon enters Earth's shadow

Europe, Africa, and Asia will have a grandstand view for the May 4 total eclipse of the Moon. This marks the last such event visible from this region until 2007. Eclipses of the Moon can be viewed by anyone on Earth's "night side." The Moon will spend 76 minutes within Earth's dark umbra. The path of the Moon takes it just south of the shadow's center.

The eclipse begins with the Moon touching the fainter shadow of the penumbra at 5:50 P.M. Universal Time (UT). At 6:48 P.M. UT, the Moon passes into the umbra. The onset of totality occurs at 7:52 P.M. UT, and mid-eclipse is 38 minutes later. The Moon's northern edge will appear darkest because it lies closer to the shadow's center. The Moon's southern limb lies in the outer edge of the shadow and will likely appear bright orange. Totality ends at 9:08 P.M. UT. The eclipse officially ends at 11:09 P.M. UT. See October for details of the year's second total lunar eclipse, which is visible from the Americas.


N
Penumbra
Umbra
E
Umbral eclipse begins 18:48 UT
Totality begins 19:52 UT
Mideclipse 20:32 UT
Totality ends 21:08 UT
Umbral eclipse ends 22:12 UT


Moon rises during eclipse
Moon sets during eclipse
Eclipse not visible
Entire eclipse visible

16 The Moon passes 3° north of Mercury, 7 P.M.

21 The Moon passes 0.3° north of Venus, 8 A.M.

22 The Moon passes 3° north of Mars, noon

The Moon passes 5° north of Saturn, 2 P.M.

24 Mars passes 1.6° north of Saturn, 7 P.M.

27 The Moon passes 4° north of Jupiter, 8 A.M.

# june:04

The 15- to 17-year interval between excellent apparitions of Mars may seem like a long time, but it's the blink of an eye compared with the wait observers have endured since the last transit of Venus. Our neighbor hasn't passed directly between Earth and the Sun since 1882, making this quirk of solar system geometry among the rarest of all celestial events.

## The transit of Venus

Only 81 transits of Venus occur between 2000 B.C. and A.D. 4000. With such rarity, observers need to be ready for the two transits coming in the next eight years. The first occurs this month, on June 8; the next one happens in June 2012.

This month's event begins at 1:14 A.M. EDT, when first contact occurs. This is when the disk of Venus apparently touches the edge of the Sun. Second contact comes 18 minutes later, when the entire disk of Venus appears in front of the Sun. As seen from Earth, Venus follows a short path across the Sun's southern hemisphere, leaving the disk at 7:26 A.M. EDT. (The exact times will vary slightly with an observer's location.)

The entire transit can be seen from eastern Africa, Europe, and all but easternmost Asia. The early stages will be visible from Australia, China, and Japan. From the eastern United States, the transit will have begun already when the Sun rises on June 8. Atlantic seaboard states will see Venus approaching the Sun's western limb. The Sun rises in Florida during the last hour of the transit.

Since 1761, the intervals between consecutive transits have been 8 years, 105.5 years, 8 years, 121.5 years, 8 years, 105.5 years, and so on. Transits repeat themselves closely every 243 years because 13 sidereal revolutions of Venus nearly equal 8 sidereal revolutions of Earth. Transits occur only during the months of December and June when Venus's orbital nodes pass across the Sun. At other inferior conjunctions, Venus passes either above or below the Sun and no transit occurs.

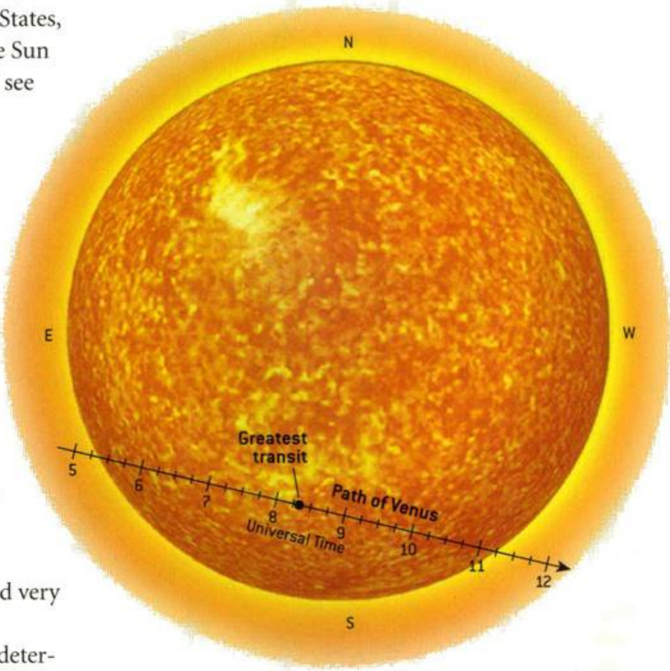
Historically, transits of Venus have proved very important. The famous British astronomer Edmond Halley came up with a method to determine the solar parallax, and hence the distance to the Sun, using observations of the transit of Venus from two locations.

Although scientists can now determine the solar parallax using other methods, the historical significance of Venus's transits heightens the level of interest beyond the scientific.

Amateur observers may join one of the many organized tour groups for a clear view of the transit. After all, no one alive has ever seen such an event. The last one occurred in 1882.

### Explore the summer sky

The Milky Way's splendor highlights the richness of the summer sky. Stretching from the north in Perseus, through Cygnus overhead, and to Sagit-



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| 20 | 21 | 22 | 23 | 24 | ◑ | 26 |
| 27 | 28 | 29 | 30 | | | |

EDT:

7 The Moon passes 5° south of Neptune, 2 A.M.

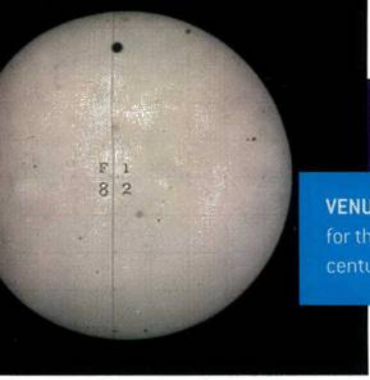
8 Venus is in inferior conjunction, 5 A.M.; transit

8 The Moon passes 4° south of Uranus, 3 P.M.

11 Pluto is at opposition, 8 A.M.

14 Mars passes 6° south of Pollux, 2 P.M.

18 Mercury is in superior conjunction, 5 P.M.

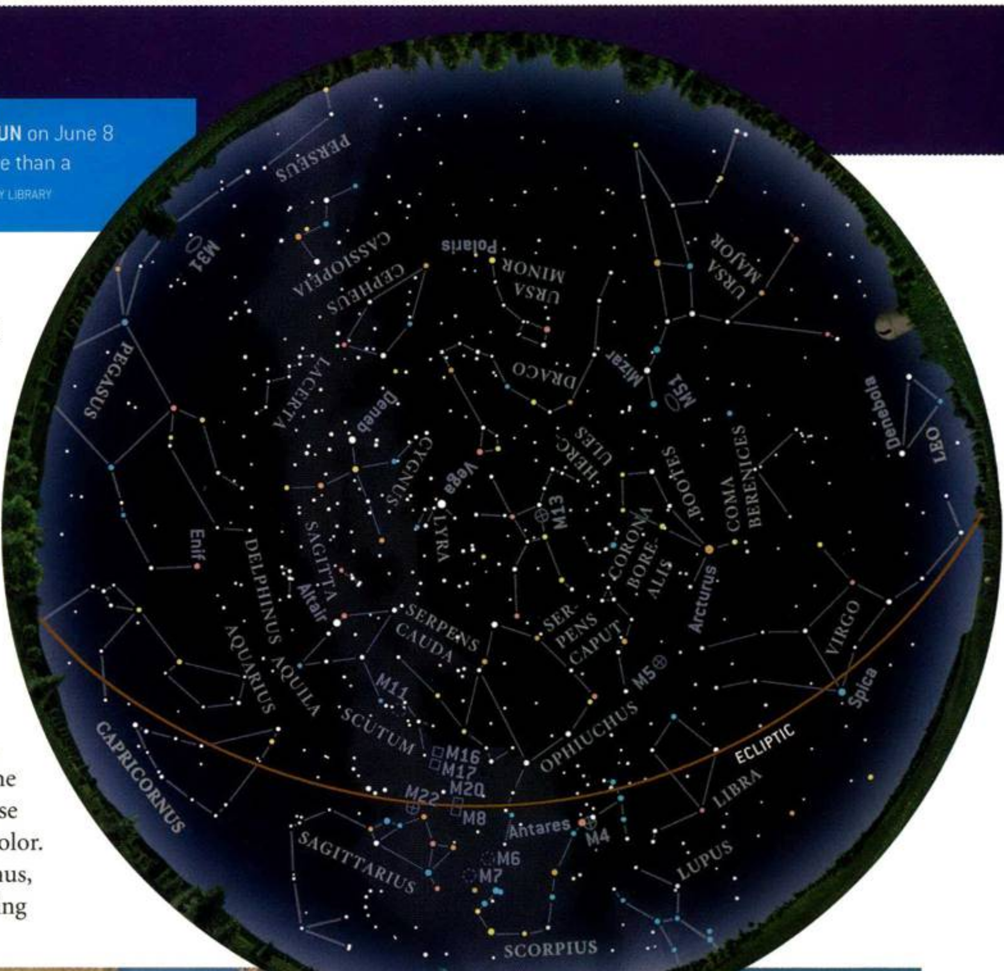


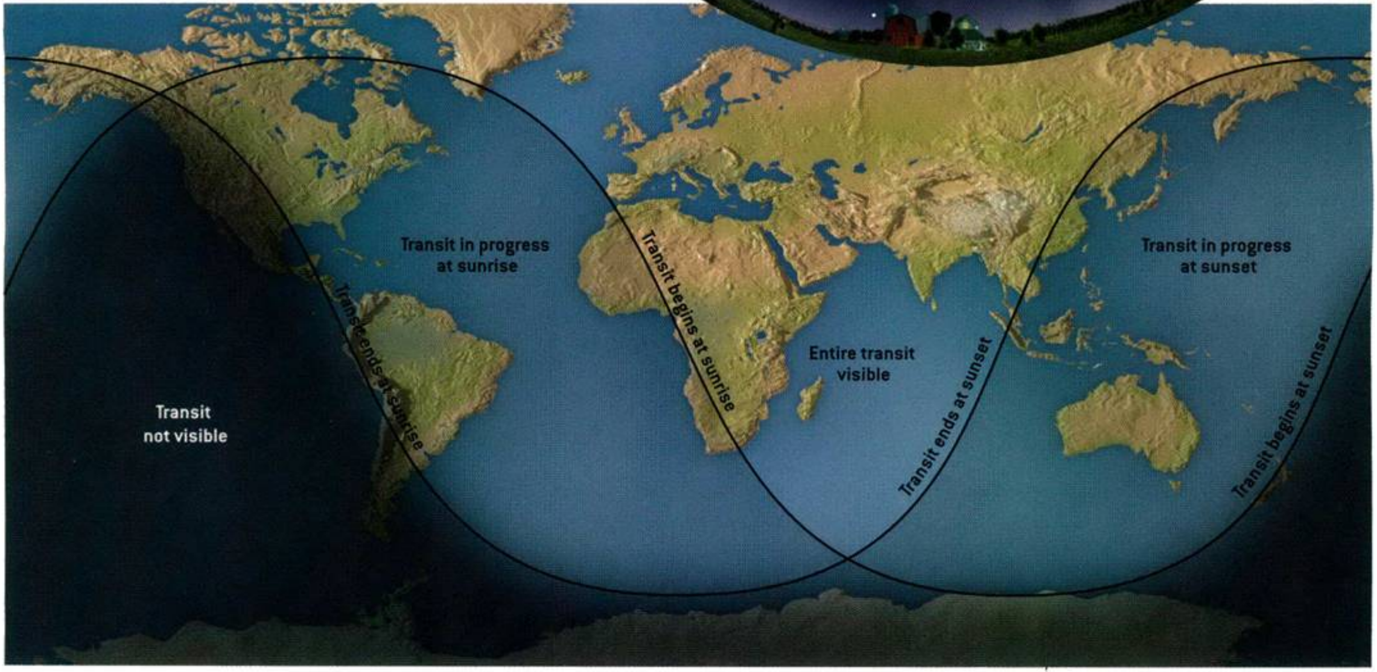
**VENUS TRANSITS THE SUN** on June 8 for the first time in more than a century. U.S. NAVAL OBSERVATORY LIBRARY

tarius in the south, the Milky Way is packed with star clusters and nebulae.

As the sky darkens on summer evenings, the first star to appear is Vega in Lyra the Harp, nearly overhead. Vega forms one corner of the Summer Triangle. To the east of Vega lies the triangle's faintest star: Deneb in Cygnus the Swan. Deneb marks the tail of this graceful bird, and its head is marked by the beautiful double star, Albireo. Altair, the third star of the Summer Triangle, is the brightest star in Aquila the Eagle.

Hugging the southern horizon, Sagittarius and Scorpius lie in the thickest part of the Milky Way. Antares is a supergiant star whose name means "rival of Mars" because of its color. The Milky Way splits into two parts in Cygnus, a giant rift caused by interstellar dust blocking more distant starlight.


PERSEUS
CASSIOPEIA
CEPHEUS
M31
Polaris
URSA MINOR
URSA MAJOR
DRACO
Mizar
M51
LACERTA
PEGASUS
Deneb
CYGNUS
Vega
LYRA
HERCULES
M13
BOÖTES
COMA BERENICES
Denebola
LEO
Enif
DELPHINUS
SAGITTA
Altair
CORONA BOREALIS
Arcturus
SERPENS CAUDA
SERPENS CAPUT
AQUARIUS
AQUILA
M11
M5
VIRGO
Spica
CAPRICORNUS
SCUTUM
M16
M17
M20
M22
M8
OPHIUCHUS
ECLIPTIC
LIBRA
Antares
M4
M6
M7
SAGITTARIUS
LUPUS
SCORPIUS


Transit in progress at sunrise
Transit ends at sunrise
Transit begins at sunrise
Transit not visible
Entire transit visible
Transit ends at sunset
Transit in progress at sunset
Transit begins at sunset

19 The Moon passes 5° north of Saturn, 3 A.M.

20 The Moon passes 4° north of Mars, 5 A.M.

20 Solstice (northern summer/southern winter begins), 9 P.M.

23 The Moon passes 3° north of Jupiter, 7 P.M.

24 Venus passes 2° north of Aldebaran, 5 P.M.

# july:04

Tracking down outermost Pluto certainly isn't for the faint of heart, but merely feeling the weak photons of planetary light falling on your retina ranks among the great thrills available to backyard observers. This summer, take time to hunt down our icy relative as it starts to cross the summer Milky Way, a prospect that bodes ill for the next few decades of Pluto watching.

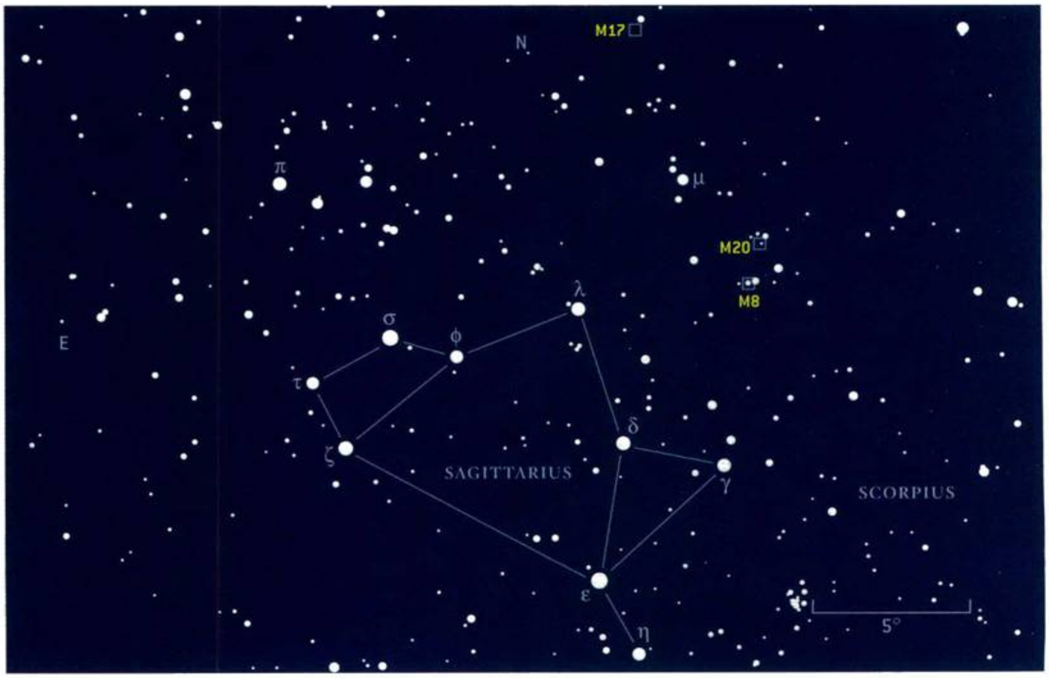
## Tracking distant Pluto

As the years pass, the difficulty in finding Pluto will only increase. The outermost planet reached perihelion — the closest point to the Sun in its orbit — in 1989, and each passing year finds it farther away and a little fainter. But even worse from the standpoint of backyard observers, Pluto is heading south into the Milky Way. The southerly position means it appears lower in the sky from the Northern Hemisphere, and the myriad stars in the Milky Way make the task of identifying the 13.8-magnitude planet that much harder.

Still, the challenge can be met. You'll need an 8-inch or larger telescope, a dark sky, and patience. Fortunately, this year finds Pluto in the company of two bright stars. When it lies opposite the Sun in our sky on June 11, it forms a near isosceles triangle with 2nd-magnitude Eta (η) Ophiuchi and 4th-magnitude Xi (ξ) Serpentis. If you imagine these two stars as the base of the triangle, Pluto forms the northern apex.

Because Pluto lies so far away — 2.9 billion miles from Earth — it moves very slowly, so you can use these same two stars as guides throughout the summer. First locate Eta Ophiuchi, then use the finder chart to hop to Pluto's location.

The chart at lower right shows stars down to magnitude 14.3, so you should be able to identify Pluto from its position relative to the background stars. (Using higher powers will help by darkening the background sky.) If not, use the tried-and-true method of experienced observers. First, sketch the eyepiece's field of view, making sure to include stars at least somewhat fainter than Pluto. Then, return to the same field a night



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**EDT:**

4 Venus passes 1.1° north of Aldebaran, 6 A.M.

The Moon passes 5° south of Neptune, 11 A.M.

5 The Moon passes 4° south of Uranus, 11 P.M.

8 Saturn is in conjunction with the Sun, 1 P.M.

8 Asteroid Juno is at opposition, midnight

10 Mercury passes 0.2° north of Mars, 7 P.M.

**SAGITTARIUS HOLDS MANY NEBULAE,** but most observers consider the best three to be the Lagoon (bottom), the Trifid (just above it), and the Swan (top left). LUKE DODD

or two later. The "star" that has changed position from your sketch is Pluto.

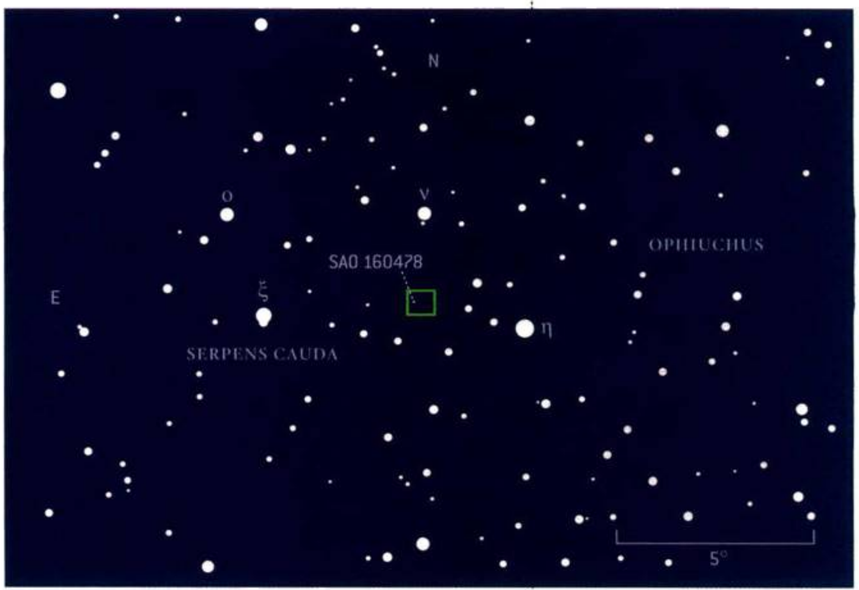
## The Archer's glowing gas

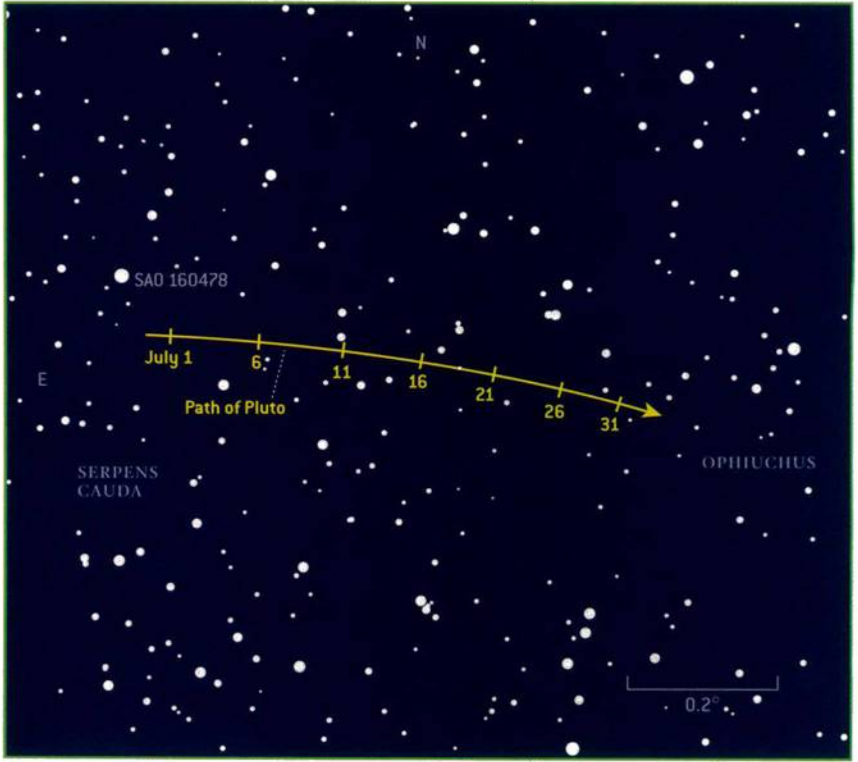
July marks the best time of year for northerners to observe the riches of the Milky Way. No constellation can match Sagittarius for Milky Way wonders because when we look in its direction, we are looking toward the center of our galaxy.

Glittering star clusters and bright emission nebulae dot the constellation. Arguably the finest of these is the Lagoon Nebula (M8), which lies just north of the spout of Sagittarius's Teapot asterism. This immense cloud of gas and dust can be seen with the naked eye under a dark sky, but it comes alive with the help of a small telescope. This cloud is slowly contracting under the influence of gravity, breaking into smaller pieces that eventually will form stars. Some massive stars have already been born here — the embedded cluster NGC 6530 contains dozens of newly minted stars.

A little more than a degree north of M8 lies the Trifid Nebula (M20). As its name implies, the Trifid appears in three parts; three dust lanes in front of the emission region appear to converge at the nebula's center. Although smaller and fainter than the Lagoon, the Trifid proves equally fascinating at moderate magnification.

The final stop on our mini-tour is the Omega, or Swan, Nebula (M17), located on the northern edge of the constellation. A modest-sized telescope shows the nebula as a bright bar with a short extension coming off the western end.





13 The Moon passes 8° north of Venus, 8 P.M.

14 Venus is at greatest brilliancy (magnitude –4.5), 9 P.M.

18 The Moon passes 4° north of Mars, 10 P.M.

19 The Moon passes 5° north of Mercury, 11 A.M.

21 The Moon passes 3° north of Jupiter, 9 A.M.

25 Mercury passes 1.5° south of Regulus, 8 P.M.

26 Mercury is at greatest eastern elongation (27°), 11 P.M.

31 The Moon passes 5° south of Neptune, 8 P.M.

# aug:04

With warm temperatures common and clear skies relatively frequent, August tops the list of many backyard observers. Toss in the best meteor shower of the year and you can't lose – unless the Moon sheds its unwanted light on the Perseids. No need to worry this year, however. The Moon will be gone at the peak of the Perseids, providing observers with wonderful views of "shooting stars."

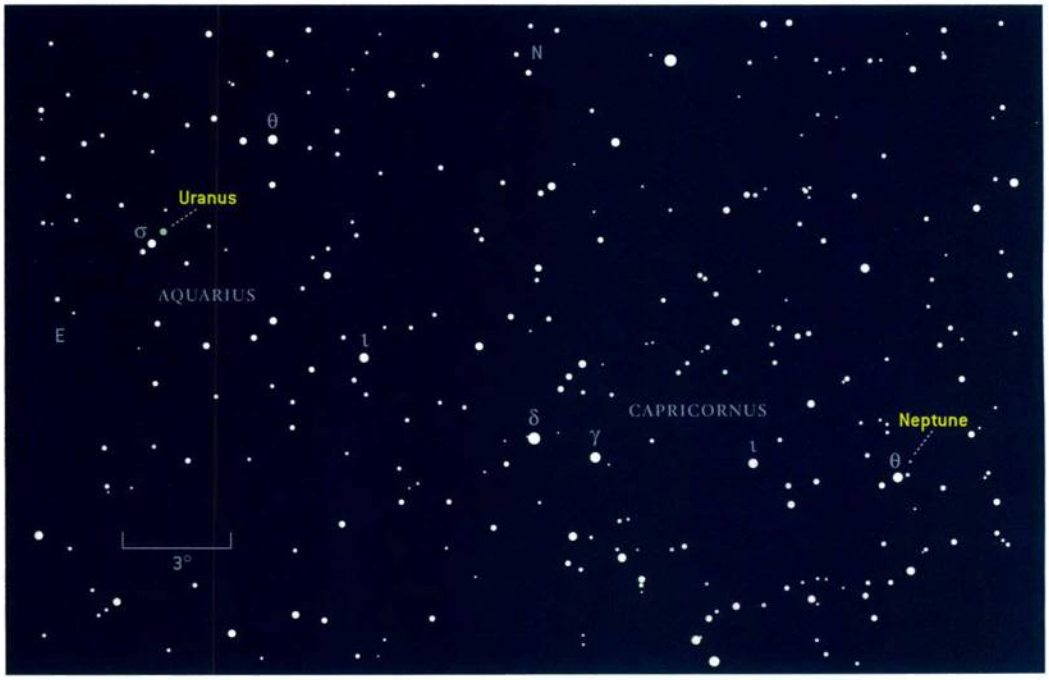
## A grand year for Perseids

"The tears of St. Lawrence," better known as the Perseid meteor shower, should put on a grand display on the night of August 12/13. Conditions this year favor this summer bonanza of "shooting stars" because the Moon doesn't interfere.

Of course, meteors have nothing to do with stars. While many meteors appear bright and flashy as they cross the sky, in real life they are nothing more than tiny particles flying through space and colliding with our atmosphere. Traveling at speeds of 37 miles per second, the typical speed of a Perseid meteoroid, any tiny particle packs a punch. Dissipate that energy in a vaporized trail and it will generate a lot of light.

Careful tracking of meteors as they plunge into the atmosphere has led to accurate orbits for many streams. That of the Perseid shower turns out to be remarkably similar to the orbit of a well known comet, Swift-Tuttle. Debris shed by this comet as it orbits the Sun generates millions of tiny particles. Earth encounters this debris between July 23 and August 20. Countless orbits of the stream around the Sun spread out the debris, which is why it takes weeks for Earth to pass through its remains. Earth moves through the main belt in a day, however, and the peak of the shower occurs between August 12 and 13.

The best time to view the Perseids comes on the morning of August 13. As Earth orbits the Sun, the part of our globe experiencing midnight to noon faces forward. Now imagine our planet as a car. Earth's morning hemisphere is the windshield of our planetary vehicle, and the meteors are the flies that get in our way. To view the



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**EDT:**

2 The Moon passes 4° south of Uranus, 8 A.M.

5 Neptune is at opposition, 11 P.M.

11 The Moon passes 8° north of Venus, 7 P.M.

12 Perseid meteor shower peaks

13 The Moon passes 5° north of Saturn, 5 A.M.

16 Mercury passes 6° south of Mars, 11 P.M.

**A PERSEID METEOR STREAKS** through the star trails of Cygnus and Lyra. DALE LIGHTFOOT

### /// METEOR SHOWERS IN 2004

| **Name** | **Peak date** | **Moon's phase** | **Prospects** |
|---|---|---|---|
| Quadrantids | January 4 | Waxing gibbous | Fair |
| Lyrids | April 21 | New Moon | Excellent |
| Eta Aquarids | May 4 | Full Moon | Poor |
| Perseids | August 12 | Waning crescent | Good |
| Orionids | October 21 | First Quarter | Good |
| Leonids | November 17 | Waxing crescent | Excellent |
| Geminids | December 13 | New Moon | Excellent |

Perseids at their best, don't look out the back window of Earth before midnight. Get into the front seat, looking out into space after midnight, and enjoy the view. You can expect to see up to 60 meteors per hour from a dark observing site.

## Uranus and Neptune slowly separate

Uranus and Neptune are the third and fourth largest planets in the solar system. Each spans about five times the size of our home planet. Yet, both Uranus and Neptune lie so far away that their telescopic appearance belies their true size. On average, Uranus is 1.7 billion miles from Earth, and Neptune lies another billion miles away. Consequently, Uranus appears only 3.7" across at its best, and Neptune manages a meager 2.4". Small size renders practically all features on each planet invisible.

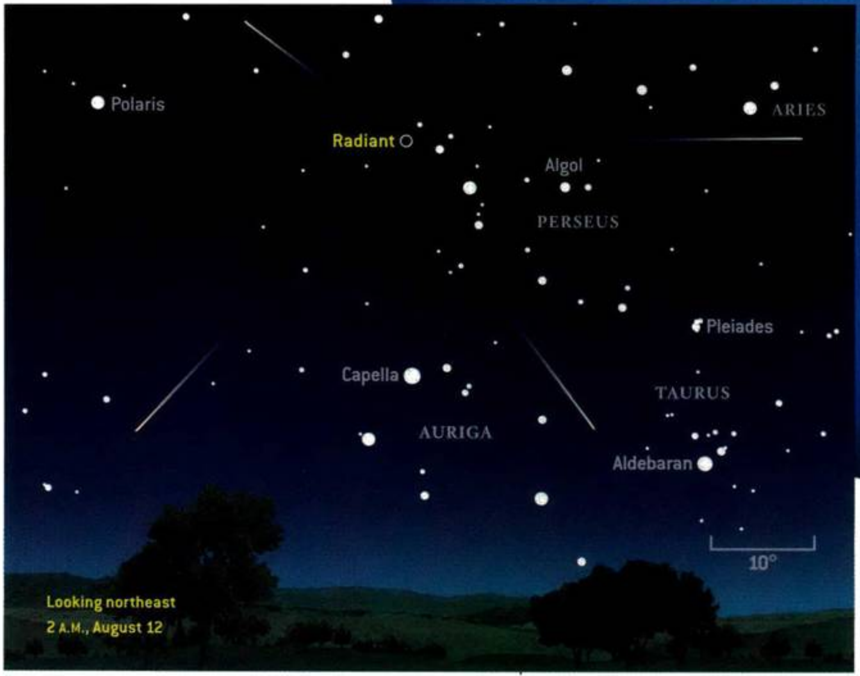
For many, the chance to see these distant worlds makes the time required to find them worthwhile. Modern go-to telescopes simplify effort, but without such features, the challenge of identification becomes part of the appeal.

Neptune currently lies in Capricornus the Sea Goat, and Uranus is just east in neighbor Aquarius the Water-Bearer. Neptune glows at magnitude 7.8 when it reaches opposition on August 6. It then lies 2.696 billion miles from Earth, and reflected sunlight takes four hours to reach us. Uranus shines at magnitude 5.8 and reaches opposition on August 27.

This year, Neptune should be relatively easy to find. Locate the 4th-magnitude star Theta (θ) Capricorni, situated in the north-central part of the constellation. On August 2, Neptune lies a Moon's breadth north of this star. Throughout July and August, Neptune remains in the same low-power telescopic field of view as Theta. Watch as the planet glides west of the star, moving just slightly from one night to the next.

Uranus shines brighter than Neptune and can be spotted with ease through binoculars. It lies in a sparse area of the sky, however. Try using the pair of stars at the eastern end of Capricornus as pointers — they indicate the direction to scan with binoculars. Follow their line east of Capricornus to a point lying well below the three stars that surround Zeta (ζ) Aquarii. There, you should find Sigma (σ) Aquarii. Uranus passes due north of this 5th-magnitude star on August 6 and remains within a binocular field of view throughout the summer months, making it an easy target.

Neptune sports a bluish color — although truth be told, it appears gray in most backyard telescopes. The blue color arises from an atmosphere rich in methane gas. Methane absorbs red light very well, causing reflected sunlight to appear blue. This image of the giant planet was taken by the Voyager 2 spacecraft from a distance of about 4.4 million miles. NASA/JPL



17 Venus is at greatest western elongation (46°), 3 P.M.

18 The Moon passes 3° north of Jupiter, 1 A.M.

23 Mercury is in inferior conjunction, 5 P.M.

27 Uranus is at opposition, 3 P.M.

28 The Moon passes 5° south of Neptune, 5 A.M.

29 The Moon passes 4° south of Uranus, 4 P.M.

31 Venus passes 1.9° south of Saturn, 9 P.M.

# sept:04

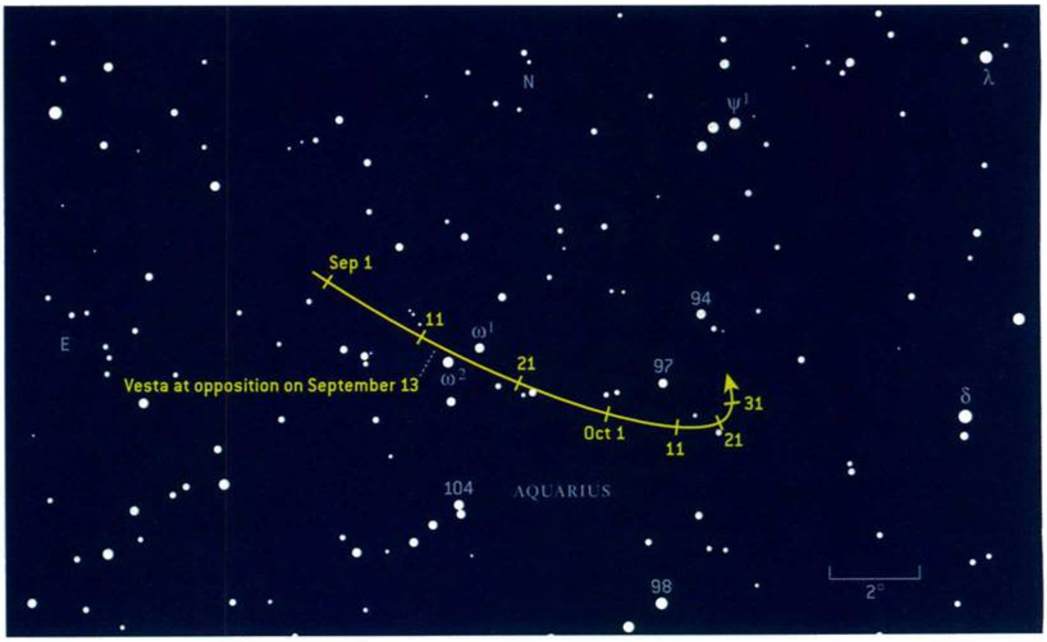
Big and bright or small and fast – asteroid observers have their choice this month. They can track down the naked-eye object Vesta as it reaches opposition in mid-September, wait until late in the month to watch Toutatis race across the sky, or try for both. The former should be a piece of cake, but the latter provides a rare opportunity to see an object actually move in the eyepiece.

## Asteroids bright and quick

Two asteroids put on excellent shows in the September sky, although their pleasures are of different varieties. Asteroid 4 Vesta reaches the peak of its 2004 apparition on September 13, when it comes to opposition. It then lies opposite the Sun in our sky, rising at sunset and appearing highest in the south around midnight. It also shines brightest at opposition: At magnitude 6.1, it lies just within reach of the naked eye from a dark site. Vesta glows brighter than any other asteroid, so this is the best one for novices eager to spot one of these minor planets.

At opposition, Vesta lies in the constellation Aquarius, which provides enough stars of similar brightness that it should be fairly easy to spot. Start with 2nd-magnitude Beta (β) Ceti, the bright star at the southwestern edge of the Whale. Head 15° due west to the trio of 6th-magnitude stars 104, 106, and 107 Aquarii. From there, it's a short hop north to 5th-magnitude Omega$^1$ ($\omega^1$) and 4th-magnitude Omega$^2$ ($\omega^2$) Aquarii. Then, simply use the finder map below to jump to Vesta's position. You should be able to identify it quickly in binoculars. Next, set them aside and see if you can detect the asteroid's faint glow without optical aid.

As its designation might suggest, asteroid 4179 Toutatis isn't among the biggest and brightest asteroids. Its claim to fame stems from its unusual orbit, which brings it close to Earth every few years. Yet, 2004 is special because Toutatis makes the closest passage to Earth of any numbered asteroid in more than 30 years. At its closest on September 29, it lies only 963,000 miles from us, just four times the average distance to the Moon.



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EDT:

1 Venus passes 9° south of Pollux, 10 P.M.

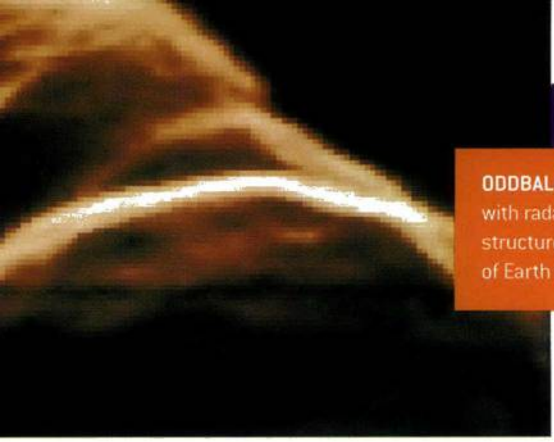
9 Mercury is at greatest western elongation (18°), 10 A.M.

9 The Moon passes 5° north of Saturn, 6 P.M.

10 Mercury passes 0.06° south of Regulus, 1 A.M.

10 The Moon passes 7° north of Venus, noon

11 Saturn passes 7° south of Pollux, midnight



**ODDBALL ASTEROID TOUTATIS,** seen here with radar, shows a distinct double-lobed structure. It passes within a million miles of Earth this month. STEVEN OSTRO (JPL), ET AL.

/// WHEN TO SEE ASTEROIDS IN 2004

| *Asteroid* | *Opposition date* | *Constellation* | *Magnitude* |
|---|---|---|---|
| 1 Ceres | January 9 | Gemini | 6.8 |
| 6 Hebe | January 12 | Canis Minor | 8.6 |
| 15 Eunomia | February 11 | Hydra | 9.0 |
| 7 Iris | March 11 | Leo | 9.0 |
| 4 Vesta | September 13 | Aquarius | 6.1 |

The close approach gives observers the rare opportunity to see an object actually move in a telescope's eyepiece. Unfortunately, Toutatis measures only a few miles across, so it never reflects enough light in our direction to appear bright. At closest approach, it glows at 10th magnitude, putting it in the range of large binoculars or a small telescope. It also lies well south at that time, among the background stars of Centaurus. Stay tuned to *Astronomy* during 2004 for more information and detailed finder charts for this speedy visitor.

## Explore the autumn sky

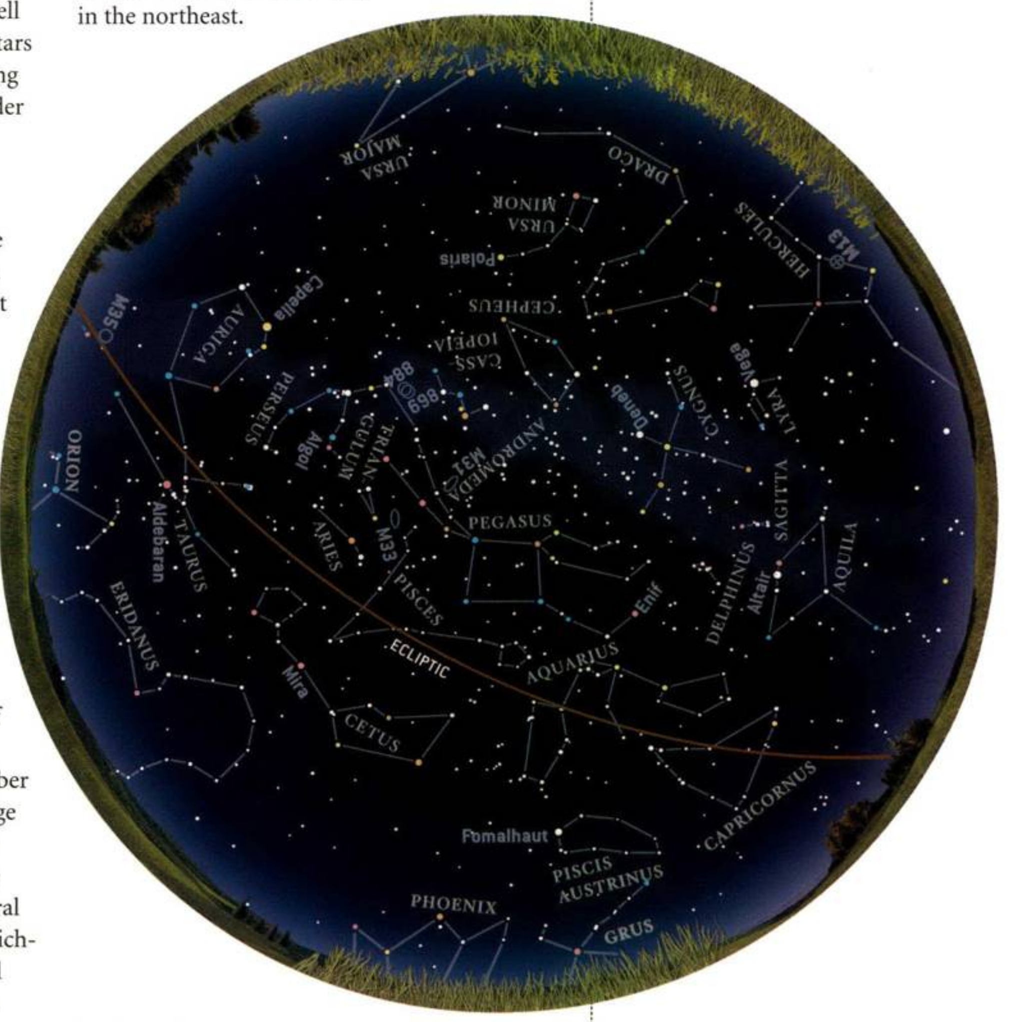
As the brilliant stars of the Summer Triangle descend in the west, they are replaced with a rather bland-looking region of sky. But don't let initial appearances deceive you. Hidden in the fall sky are gems equal to or better than those of summer.

Cassiopeia, a group of five bright stars in the form of a "W" or "M" (depending on the time of night and time of year), lies directly overhead. To its east, Perseus rises high. Nestled between these two groups is the wonderful Double Cluster — NGCs 869 and 884 — a fantastic sight in binoculars or a low-power telescope.

Our view to the south of the Milky Way affords us a good look at the Local Group of galaxies. Due south of Cassiopeia lies the Andromeda Galaxy (M31), the largest member of the Local Group. A 4th-magnitude smudge of light, M31 passes overhead on November evenings. A little farther to the south lies the Pinwheel Galaxy (M33), a large, face-on spiral in Triangulum best seen in binoculars or a rich-field scope. It ranks as the third largest Local Group galaxy, after M31 and the Milky Way.

The Great Square of Pegasus passes just south of the zenith on autumn evenings. If you draw a line between the two stars on the square's right side and extend it southward, you'll find 1st-magnitude Fomalhaut, the lone bright star low in the south.

East of the square lies the Pleiades star cluster (M45) in Taurus, which reminds us that winter lurks not far in the future. By midnight in September, Taurus and Orion have cleared the horizon and Gemini is rising in the northeast.


URSA MAJOR
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URSA MINOR
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CEPHEUS
CASSIOPEIA
HERCULES
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Vega
LYRA
CYGNUS
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Capella
AURIGA
M35
PERSEUS
869
884
Algol
TRIANGULUM
ANDROMEDA
M31
ORION
Aldebaran
TAURUS
ARIES
M33
PISCES
PEGASUS
SAGITTA
DELPHINUS
Altair
AQUILA
Enif
AQUARIUS
ECLIPTIC
ERIDANUS
Mira
CETUS
CAPRICORNUS
Fomalhaut
PISCIS AUSTRINUS
PHOENIX
GRUS

12 The Moon passes 4° north of Mercury, 9 P.M.

13 Asteroid Vesta is at opposition, 3 A.M.

15 Mars is in conjunction with the Sun, 9 A.M.

21 Jupiter is in conjunction with the Sun, 8 P.M.

22 Equinox (northern autumn/southern spring begins), noon

24 The Moon passes 5° south of Neptune, 11 A.M.

25 The Moon passes 4° south of Uranus, 11 P.M.

29 Asteroid Toutatis passes close to Earth, 10 A.M.

# oct :04

A short-lived glut of total lunar eclipses visible from North America ends this month. For the third time in a year and a half, observers can see the Moon dip completely into Earth's shadow, taking on a ruddy hue representing all the world's sunrises and sunsets. But don't miss this opportunity: Your next chance to witness totality won't come until March 2007.

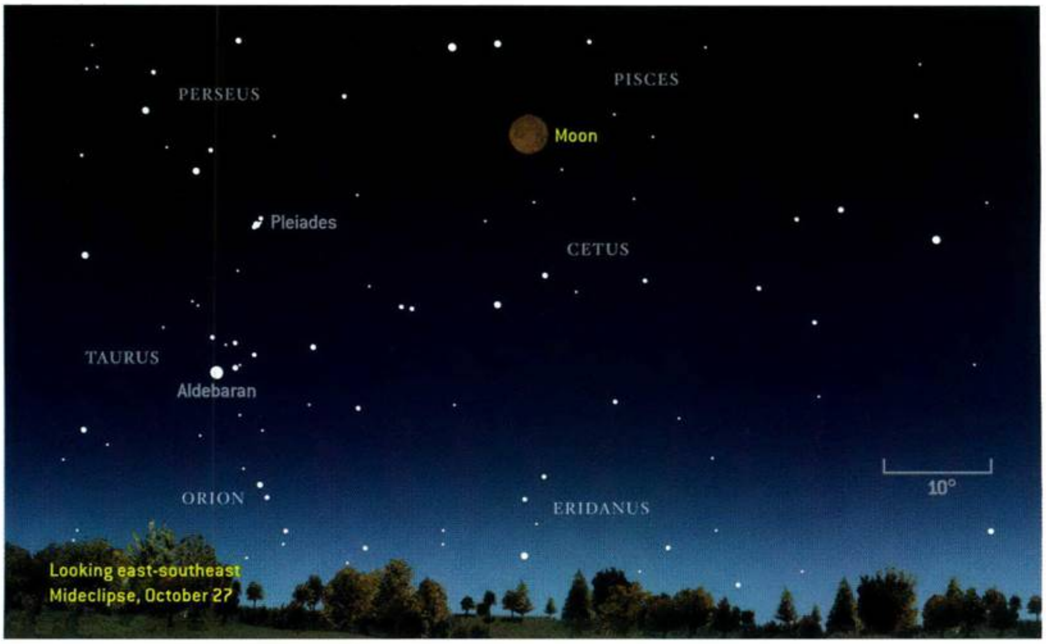
## Totality for the Americas

North and South America will be treated to a pre-Halloween total eclipse of the Moon on October 27. Observers in Europe, western Africa, and the Middle East also will see the eclipse, although the date will have clicked over to early morning on the 28th.

October's Full Moon, also known as the Hunter's Moon because its bright light used to aid hunters in seeking their quarry, begins to slide into Earth's lighter, penumbral shadow shortly after 8 P.M. EDT on the 27th. A half hour later, a noticeable darkening will appear on the left edge of the Moon, which lies high in the eastern sky. At 9:14 P.M. EDT, the Moon reaches the edge of the darkest part of the shadow, called the umbra. For the next 69 minutes, the Moon will pass deeper and deeper into Earth's shadow during the partial phases of the eclipse.

Initially the shadow will appear black in contrast to the rest of the Moon, which remains in bright sunshine. As the partial phases progress, however, and more of the lunar surface becomes hidden in shadow, the Moon starts to take on an orange hue. The color grows brighter by the time totality begins at 10:23 P.M. EDT.

Totality lasts for 81.3 minutes, wrapping up at 11:45 P.M. EDT. During the next hour or so, the Moon slides back into sunlight. The partial umbral phase concludes at 12:54 A.M. EDT on the 28th and the eclipse officially ends as the Moon clears the penumbral shadow at 2:03 A.M. EDT. This is the third total lunar eclipse visible from at least part of the Americas in the past year and a half. Unfortunately, it's also the last one visible anywhere for quite a while. The next total eclipse won't come until March 2007.



Looking east-southeast
Mideclipse, October 27

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| 31 | | | | | | |

EDT:

3 Venus passes 0.2° south of Regulus, noon

5 Mercury is in superior conjunction, 3 P.M.

7 The Moon passes 5° north of Saturn, 6 A.M.

10 The Moon passes 4° north of Venus, 3 P.M.

12 The Moon passes 1.6° north of Jupiter, 3 P.M.

13 Partial solar eclipse, 11 P.M.

**A RUDDY MOON** bathes in sunlight that has been refracted into Earth's shadow. The Americas will see such a Moon during the total lunar eclipse on October 27. MICHAEL TOH

**A PARTIALLY ECLIPSED SUN** will greet observers in Alaska and Hawaii near sunset on October 13. JIM ROSTIROLLA

## Solar eclipse in Alaska and Hawaii

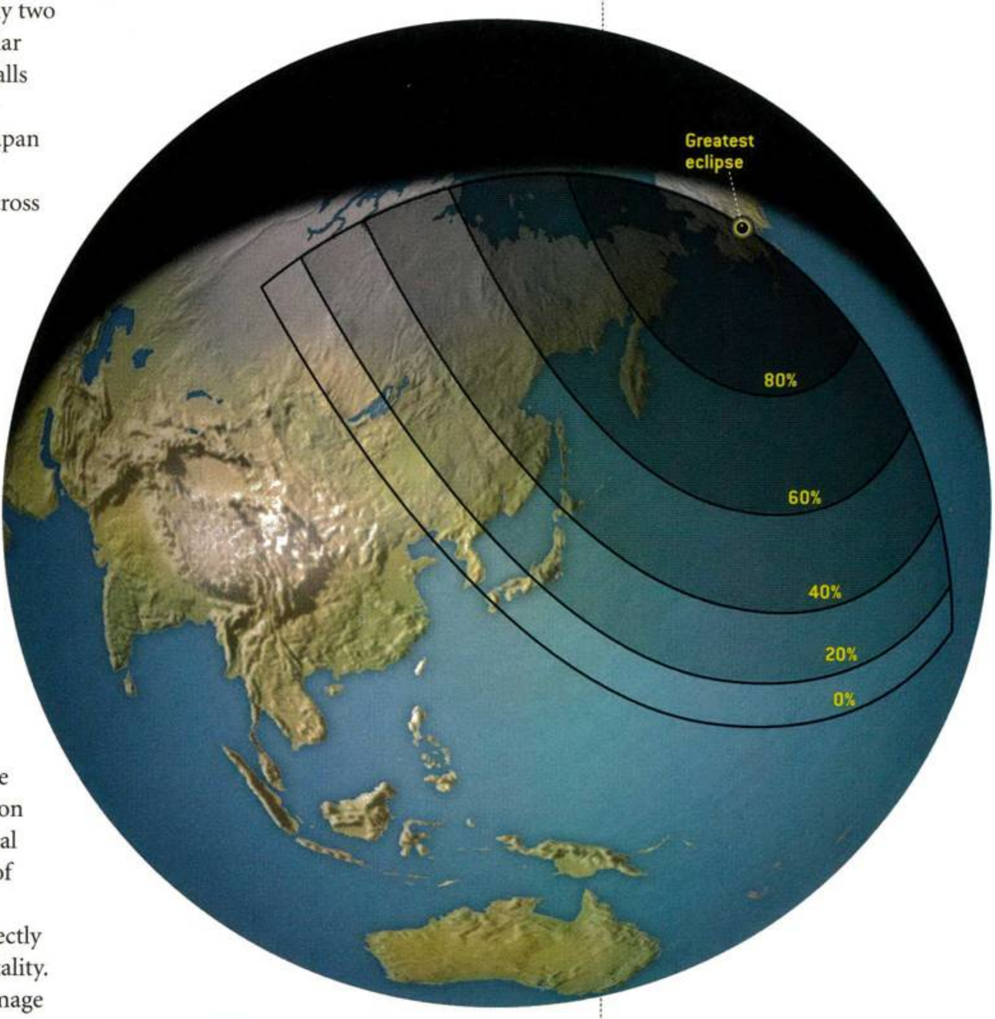
Alaska and Hawaii join northern Asia in seeing a partial eclipse of the Sun this month, exactly two weeks before the total lunar eclipse. The solar eclipse begins as the shadow of the Moon falls on northern Siberia, progresses toward the Pacific Ocean, and passes over Korea and Japan on the morning of October 14.

Curiously, the eclipse ends near sunset across the Pacific on the previous day, October 13. Observers in Alaska and Hawaii see it on a different date because the eclipse's path crosses the international date line.

In Anchorage, Alaska, the eclipse begins at approximately 5:55 P.M. local time, and maximum eclipse occurs near sunset. The Sun will set as a crescent in the western sky, with approximately 75 percent of its diameter blocked by the Moon shortly after 6:40 P.M. local time. You'll need a clear western horizon to see this view. If mountains limit your line of sight, the Sun will hide behind your horizon earlier and less of it will be eclipsed.

In Honolulu, Hawaii, a similar situation occurs. The eclipse begins at approximately 6:13 P.M. local time. Observers should situate themselves where they have a clear sea horizon to the west. At sunset, shortly after 7 P.M. local time, the Moon covers a little less than half of the Sun's diameter.

As with any solar eclipse, never look directly at the Sun outside the brief moments of totality. For safe viewing, always project the Sun's image or use a certified solar filter that fits over the front end of your telescope.



21 Orionid meteor shower peaks

The Moon passes 5° south of Neptune, 5 P.M.

23 The Moon passes 4° south of Uranus, 4 A.M.

27 Total lunar eclipse, 11 P.M.

31 Mars passes 3° north of Spica, 3 A.M. EST

# nov :04

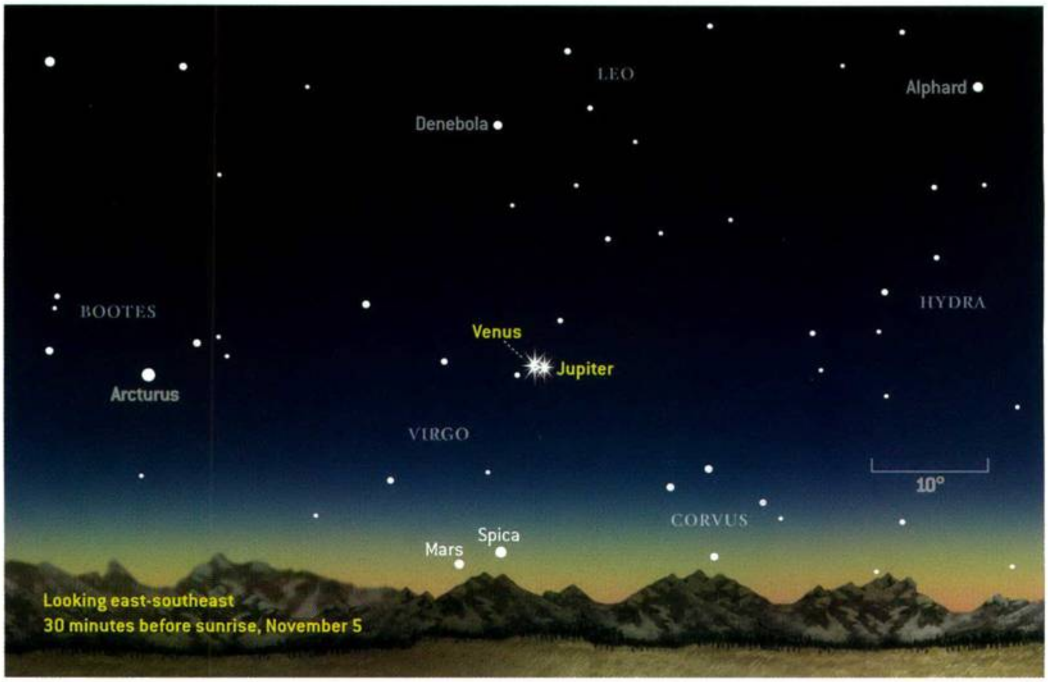
# Jupiter meets Venus

"Conjunction" may sound like a boring word, but when the two brightest planets in the night sky team up, you have a recipe for excitement. Watch as Venus approaches Jupiter during the first few evenings of November, then passes it on the 5th. If you tried to squeeze a Full Moon between the planets that night, the dazzling beacons would nearly scrape the surface of our satellite.

The two brightest planets, Jupiter and Venus, lie close to one another in the morning sky on November 5. Just before dawn in the sky over America, Jupiter, shining at magnitude –1.7, and Venus, shining at magnitude –4.0, meet in the constellation Virgo the Maiden. Only 0.7°, slightly more than one Moon width, separates the pair. This conjunction finds both planets close enough to be seen in the same low-power telescopic field of view. The spectacular pairing is the first of a few events during November. Mars, lying 17° below Venus and much fainter at magnitude 1.7, proves more challenging to spot as the eastern horizon brightens.

The Last Quarter Moon hangs high above the bright pair of planets, and during the days following November 5, it advances toward them. Simultaneously, Jupiter and Venus appear to separate. By November 9, the waning crescent Moon sits very close to Jupiter. For some areas, the Moon will hide, or occult, Jupiter. The occultation will be visible in daylight from Canada, northern states like Wisconsin and Minnesota, and East Coast states except most of Florida. In all other locations, Jupiter will appear less than a degree from the crescent Moon.

The Moon also occults Venus, Mars, and Mercury over the next few days as it moves toward New Moon on November 12. The Moon occults Venus on November 10 for observers in southern Asia, Australia, and New Zealand. Observers in East Africa, southern Australia, and New Zealand are in the right location for the November 11 occultation of Mars. Finally, it's Mercury's turn



**Looking east-southeast**
**30 minutes before sunrise, November 5**

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| 28 | 29 | 30 | | | | |

## EST:

3 The Moon passes 5° north of Saturn, 3 P.M.

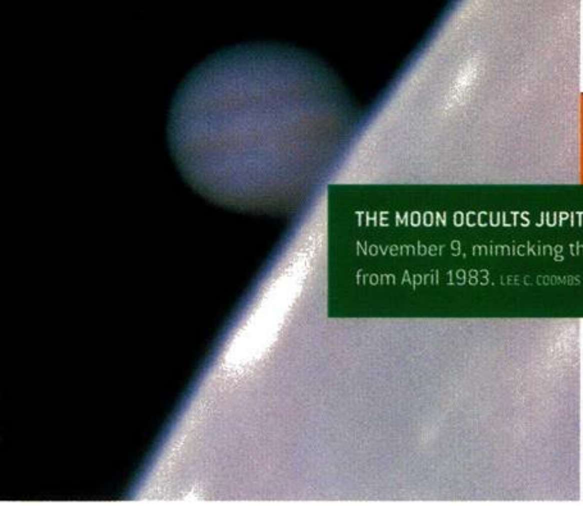
4 Venus passes 0.6° north of Jupiter, 4 P.M.

9 The Moon passes 1.0° north of Jupiter, 11 A.M.

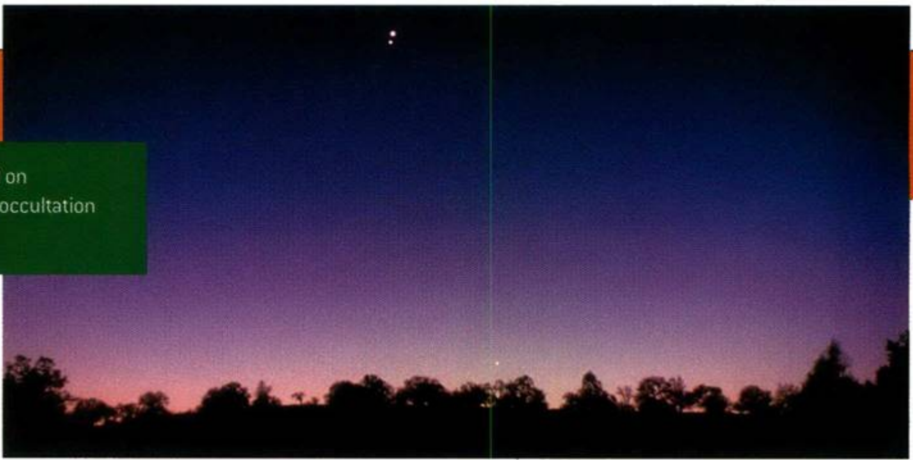
The Moon passes 0.2° south of Venus, 9 P.M.

10 The Moon passes 0.5° south of Mars, 11 P.M.

11 Mercury passes 2° north of Antares, 5 A.M.



**THE MOON OCCULTS JUPITER** on November 9, mimicking this occultation from April 1983. LEE C. COOMBS



**VENUS AND JUPITER** lie close to each other in the morning sky at the beginning of November. Venus is the brighter of the pair. LEE C. COOMBS

on November 14, but few will see this event. Not only will the pair be very close to the Sun, but also the region of visibility lies over Antarctica.

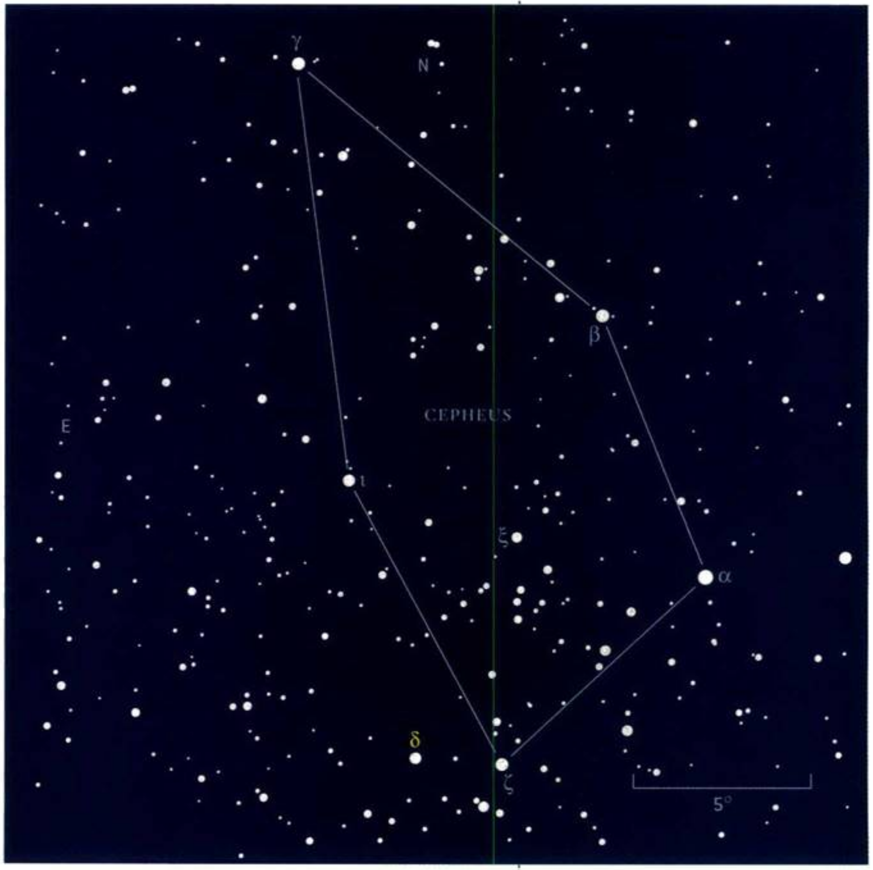
## Follow the pulsating star

The Andromeda Galaxy (M31) lies 2.6 million light-years from Earth, the Virgo Cluster of galaxies about 50 million light-years. Have you ever wondered how astronomers measure such distances? The answer lies in the autumn sky, with the extraordinary star Delta (δ) Cephei, which at first glance appears unassuming.

In 1784, astronomer John Goodricke noticed that Delta Cephei varied from magnitude 3.6 to 4.3 and back again in a period of 5.366 days. Over the years, astronomers found a host of other stars showing similar patterns of variation, although the periods ranged between a couple of days and about 50 days. They became known as Cepheid variables, named after the prototype found in the constellation Cepheus.

The breakthrough came in 1912, when astronomer Henrietta Leavitt discovered 25 Cepheids in the Small Magellanic Cloud, a satellite galaxy of the Milky Way. She found that the brighter a Cepheid appeared, the longer it took to go from maximum light to minimum light and back. Once astronomers calibrated this so-called period-luminosity relation through observations of a few nearby Cepheids, they could calculate the distance to any Cepheid. Because all Cepheids are luminous supergiant stars, they can be seen across vast distances, even in galaxies tens of millions of light-years away.

Autumn evenings provide a good opportunity to follow Delta Cephei's changing brightness. First locate Cepheus, which passes nearly overhead on late fall evenings. Delta lies just off the southeastern corner of this house-shaped constellation. Watch the star every clear night over the course of a week or two, and compare its brightness with those of the surrounding stars. With practice, you'll notice its brightness changing with a predictable pattern; it is the pulsating heart of the universe's most important yardstick.



13 The Moon passes 0.9° south of Mercury, 10 P.M.

16 Venus passes 4° north of Spica, 4 A.M.

17 Leonid meteor shower peaks

The Moon passes 5° south of Neptune, 10 P.M.

19 The Moon passes 4° south of Uranus, 8 A.M.

20 Mercury is at greatest eastern elongation (22°), 8 P.M.

30 The Moon passes 5° north of Saturn, 9 P.M.

# dec :04

This could turn out to be the year of Saturn. Always a stunning object in small telescopes, it dazzles in the evening during the first part of 2004 and in the morning late in the year. But Saturn's biggest claim to fame will be the attention it receives when the Cassini spacecraft arrives in July to start a four-year reconnaissance that will transform our knowledge of the Ringed Planet.

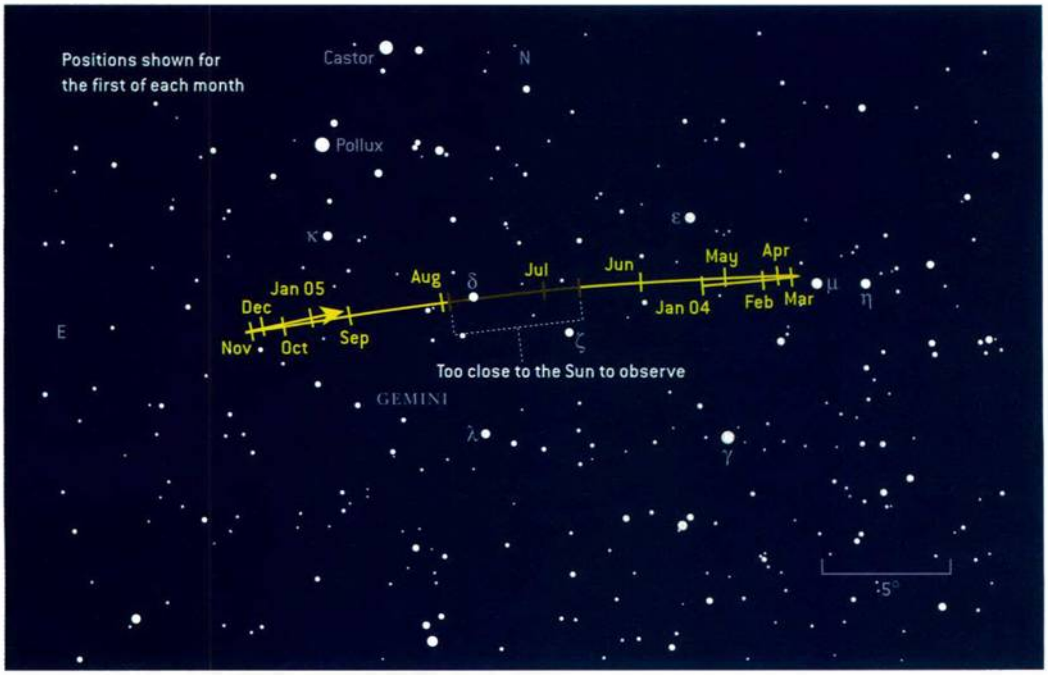
# And Saturn makes three

Atypically, Saturn does not reach opposition in 2004. Although this holds no real significance, it's one of those conversation pieces that can lead to a deeper understanding of the motions of the planets. It happens because our calendar year is slightly shorter than the synodic period of Saturn. Saturn's most recent opposition occurred on December 31, 2003. The synodic period of Saturn, the period between two consecutive oppositions, measures 378 days. Any opposition in the last 13 days of December results in the lack of an opposition the following calendar year.

Notwithstanding these semantic details, 2004 will be the year of Saturn. If all goes well, NASA's Cassini spacecraft will begin orbiting Saturn in July, and the European Space Agency's Huygens probe will be ready to drop into the atmosphere of Titan, the planet's largest moon, forever changing our view of the entire saturnian system.

Saturn spends the year in Gemini the Twins. In January, it stays visible all night and begins a slow and gentle slide toward its midsummer conjunction with the Sun. Following its early morning reappearance from behind the Sun, Saturn stands more than 20° from our star in early August. That angle grows by approximately 1° each day, driving Saturn higher into the predawn sky. On September 1, Saturn passes 1.9° north of Venus, forming a brilliant pair in the morning sky with the twin stars of Castor and Pollux looking over them.

As the solar system's second largest planet, Saturn usually offers a nice telescopic view, but few people brave the early morning hours. By the



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| 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| ● | 27 | 28 | 29 | 30 | 31 | |

EST:

5 Venus passes 1.3° north of Mars, 2 A.M.

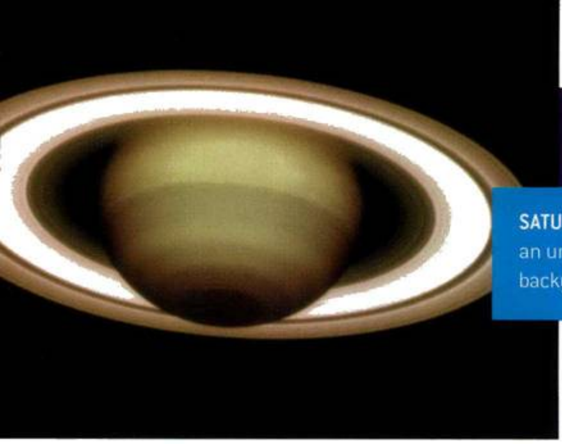
7 The Moon passes 0.3° north of Jupiter, 6 A.M.

9 The Moon passes 2° south of Mars, 7 P.M.

The Moon passes 4° south of Venus, midnight

10 Mercury is in inferior conjunction, 3 A.M.

13 Pluto is in conjunction with the Sun, noon



**SATURN'S MAGNIFICENT RINGS** make for an unforgettable treat when seen through backyard telescopes. ESO

time December rolls around, however, Saturn rises in the east at about 8:30 P.M. local time. It climbs to a decent altitude by 10 P.M., which is early enough for most observers to take a peek at the most beautiful view in the sky.

If you get a new telescope for Christmas, try spotting Saturn just below the Moon on December 27. The nearly full Moon lies just below the two bright stars of Gemini, Castor and Pollux. Saturn appears 5° farther south and shines at magnitude –0.3, brighter than Castor or Pollux.

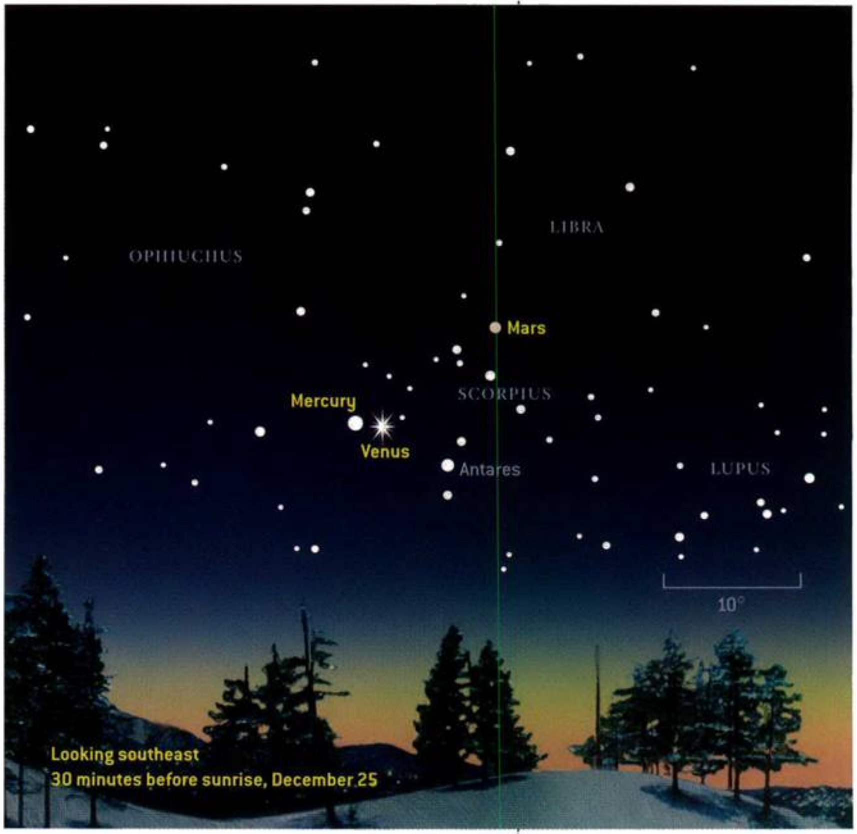
Any telescope vividly shows the planet's rings, currently tipped so we have a good view of their southern face. Avoid the temptation to crank up the magnification. Higher-power eyepieces may fuzz the image, magnifying tiny atmospheric disturbances as much as the planet itself. A smaller, crisper image through a lower-power eyepiece often proves more satisfying.

## A morning congregation

Rise early on Christmas morning, before sunrise, and if a clear sky greets you, look to the southeast. There, you will be presented a special gift, the brilliant planet Venus standing just four Moon-widths away from Mercury. Through a telescope, Venus exhibits a nearly full phase on a tiny disk just 11" in diameter. It lies on the far side of the Sun from Earth, some 140 million miles away. Mercury, smaller than Venus yet closer at 86 million miles away, shows a 50-percent-lit disk that measures 7" across.

But there's more. Mars stands 11° west of Venus on December 25. Don't confuse Mars, shining at magnitude 1.6, with its ancient "rival," the star named Antares, which shines at magnitude 1.0. Antares lies below Mars and at roughly the same altitude as Venus. Jupiter stands high above the southern horizon at dawn throughout December. Also, Saturn hovers above the western horizon. That makes five planets on view each morning.

Earlier in the month, on December 9, the eastern horizon sports a bright, shiny Venus standing a little more than four Moon-widths east of Mars. A slender crescent Moon joins Mars and Venus, producing an elegant view in the crisp dawn. Mars and Venus appear closest on December 5, when Mars lies 1.3° north of the much brighter planet. During the days that follow, Mars pulls higher in the sky while Venus drops to meet Mercury. Mercury pops out of the dawn glow in mid-December and lies 1.2° from Venus on December 29, rounding off a spectacular year of planetary delights. ■



Looking southeast
30 minutes before sunrise, December 25

13 Geminid meteor shower peaks

15 The Moon passes 5° south of Neptune, 6 A.M.

16 The Moon passes 4° south of Uranus, 4 P.M.

21 Solstice (northern winter/southern summer begins), 8 A.M.

23 Venus passes 6° north of Antares, 4 P.M.

28 The Moon passes 5° north of Saturn, 1 A.M.

28 Mercury passes 1.2° north of Venus, midnight

29 Mercury is at greatest western elongation (22°), 4 P.M.

# Spring's comet spectacular

## A pair of bright comets will grace the evening sky during the spring of 2004. /// BY RICHARD TALCOTT

Observing comets has to rank among the most fickle of astronomical pursuits. Years — sometimes decades — can go by without even a hint of a bright comet. Then a spectacular comet races past Earth, followed just months later by a second, equally impressive visitor. That's what happened in the late 1990s, when Comet Hale-Bopp delighted observers while memories of Comet Hyakutake remained fresh.

The spring of 2004 could prove just as memorable. If predictions hold true — never a sure thing when it comes to estimating the brightness of a comet making its first recorded trip into the inner solar system — May will bring two 1st-magnitude comets. That would make them as bright as the prominent spring stars Regulus in Leo and Spica in Virgo. But even if the comets don't live up to expectations, they still should be easy naked-eye objects under a dark sky.

Originally estimated to shine at 20th magnitude, Comet C/2001 Q4 (NEAT) was discovered by the Near-Earth Asteroid Tracking team at NASA's Jet Propulsion Laboratory using the

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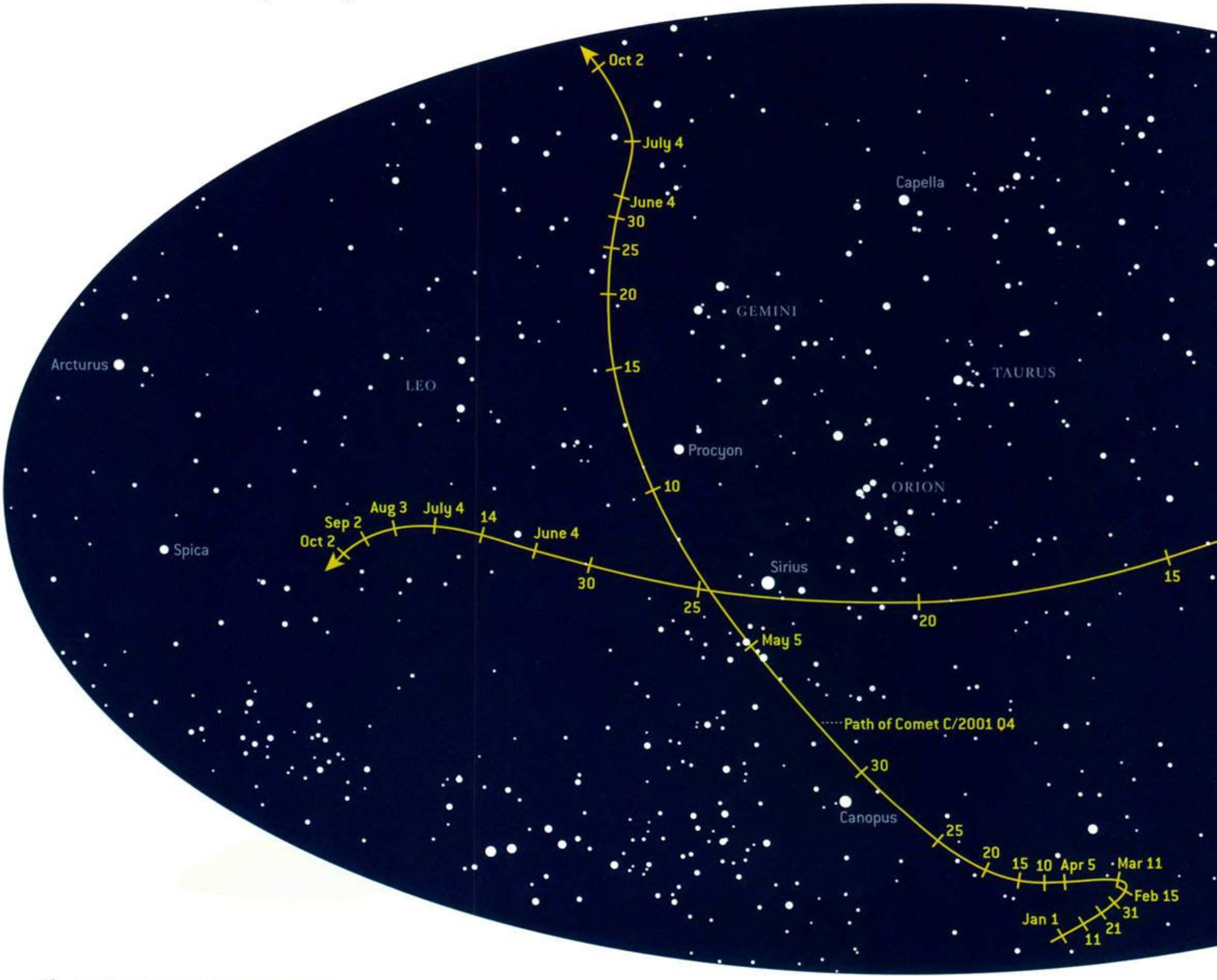
**Richard Talcott** *is senior editor of* Astronomy.


Oct 2
July 4
June 4
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May 5
Path of Comet C/2001 Q4
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Apr 5
Mar 11
Feb 15
31
21
11
Jan 1
Capella
GEMINI
TAURUS
LEO
Arcturus
Procyon
ORION
Spica
Sirius
Canopus
Sep 2
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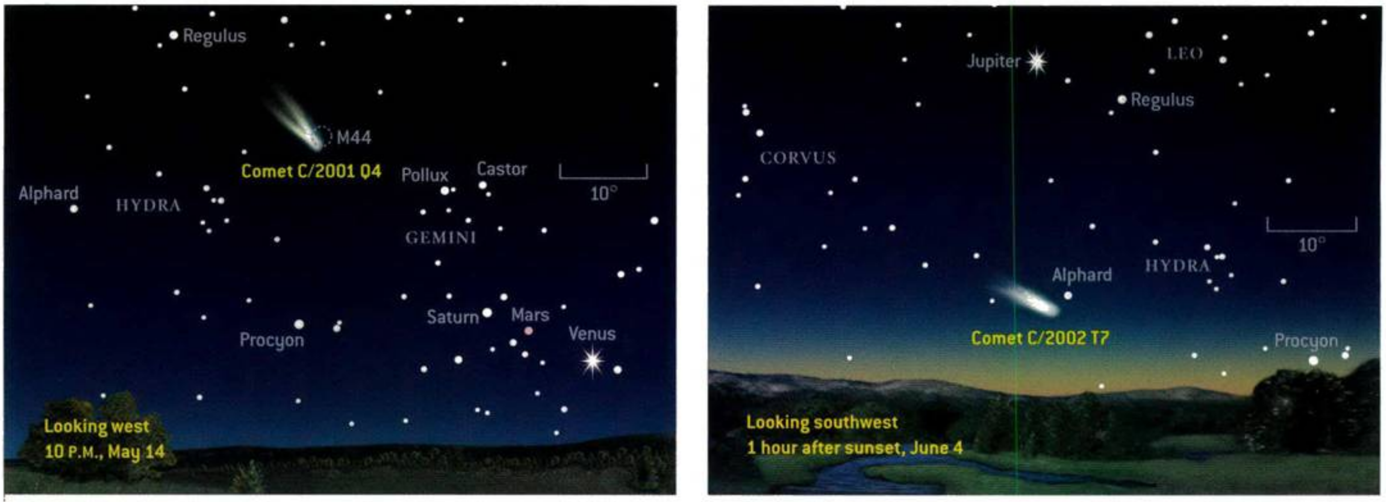


**PHOTO OPPORTUNITIES ABOUND** with two naked-eye comets this spring. Northern Hemisphere observers can watch Comet C/2001 Q4 (NEAT) buzz past the Beehive star cluster (M44) on May 14, and a few weeks later, they will get their best view of Comet C/2002 T7 (LINEAR). MAPS BY TERRI FIELD AND ROEN KELLY

48-inch Schmidt Telescope at Palomar Observatory. The comet's speed at discovery was sluggish, owing to its large distance from the Sun (approximately 11 times that of Earth's). But like every object in the solar system, the comet will accelerate as it approaches the Sun. At its fastest in May, it will cover more than 5° per day, the equivalent of traversing the Moon's diameter every two hours.

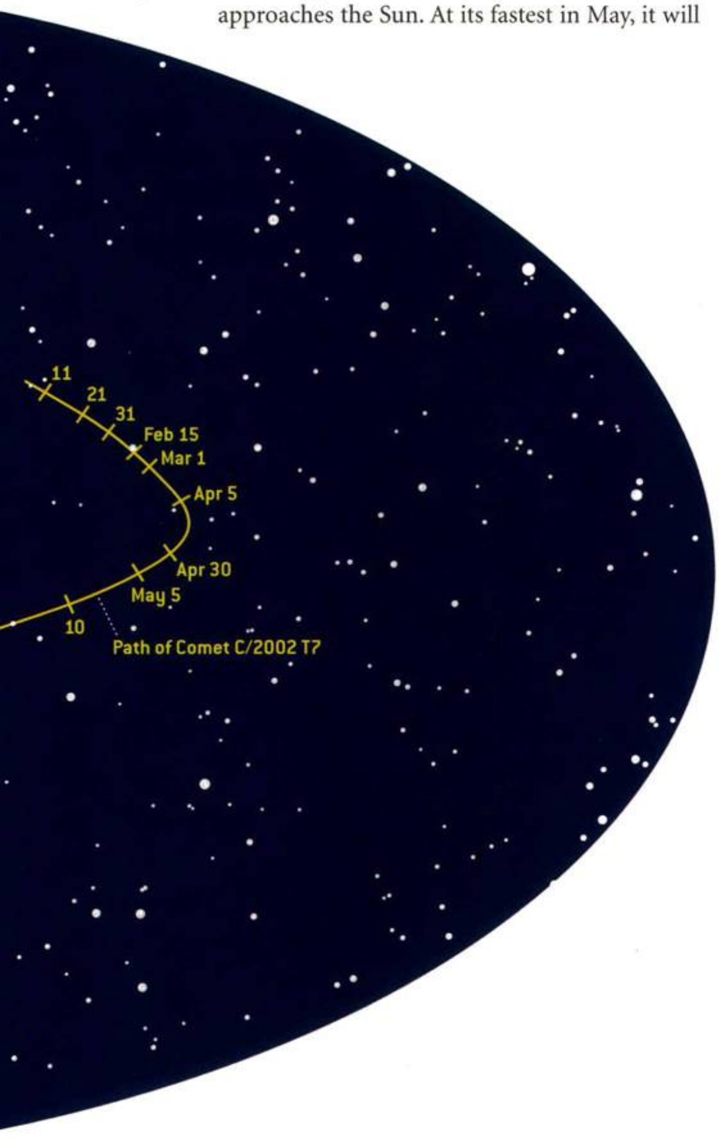
This comet spends the first four months of 2004 deep in the southern sky, but as it passes closest to Earth in May, it speeds northward. That means Northern Hemisphere observers will get a better show than their southern counterparts.

The comet will be visible to the lucky northerners by the end of the first week of May, when it appears low in the west as twilight fades to darkness. As it rushes from Monoceros through Canis Minor and into Cancer, it gains significant altitude with each passing day. On the evening of May 14, it skims less than 2° west of the prominent Beehive star cluster (M44), presenting a nice photo opportunity. It next heads into Lynx and then Ursa Major, where it remains from late May until August. The comet should reach a peak brightness of 1st magnitude during the first half of May and fade slowly over the next several weeks. It ends May at around 3rd magnitude and should remain visible to the naked eye until late June.

Southern Hemisphere observers, however, will have the upper hand with Comet C/2002 T7 (LINEAR), which was discovered in October 2002 by MIT's Lincoln Laboratory Near Earth Asteroid Research project. Unlike C/2001 Q4 (NEAT), which speeds south to north, C/2002 T7 (LINEAR) charges west to east as it hurtles past Earth. For southern observers, it moves from an easy, morning object on May 15 to an easy, evening object just five days later. It should shine around 1st magnitude or perhaps a little brighter by the 20th. It continues gaining altitude through early June and remains nicely placed until it dips below naked-eye visibility in late June.

The geometry of the comet's passage favors the Southern Hemisphere because sunset and twilight occur earlier each evening as winter approaches. The Northern Hemisphere faces the opposite effect as summer draws near. The best chance for northerners to spy the comet will come during the second week of June, when it should shine at 4th magnitude and appear low in the west-southwest as darkness falls.

Use the all-sky map to track both comets throughout 2004. Their positions are plotted for the evening hours. And keep following *Astronomy* for further details about these comets — and any others that might happen to surprise us. ■



# Good site + good night = observing joy

Maximize your observing experience by following a few simple guidelines. /// BY TERENCE DICKINSON

Reading this first sentence is almost impossible due to the glare behind it. Observing the night sky near a source of light pollution can present the same problem. It used to be easy. You just stepped into the backyard after dark, looked up, and if the sky was clear, you set up your telescope for a night's observing. For most of us, however, those days are long gone. The brightness of the night sky over a 21st-century backyard is more likely to be illumination from streetlights than from starlight. Today, light pollution is a fact of life.

Yes, there is a growing trend among enlightened municipal and state agencies to use "full-cutoff" light fixtures to reduce glare and skyward-directed lighting. But the reality is that thousands of new streetlights are being installed daily across the country and around the globe. Even the best lighting fixtures, which keep all their light shining downward, still add to the sky glow.

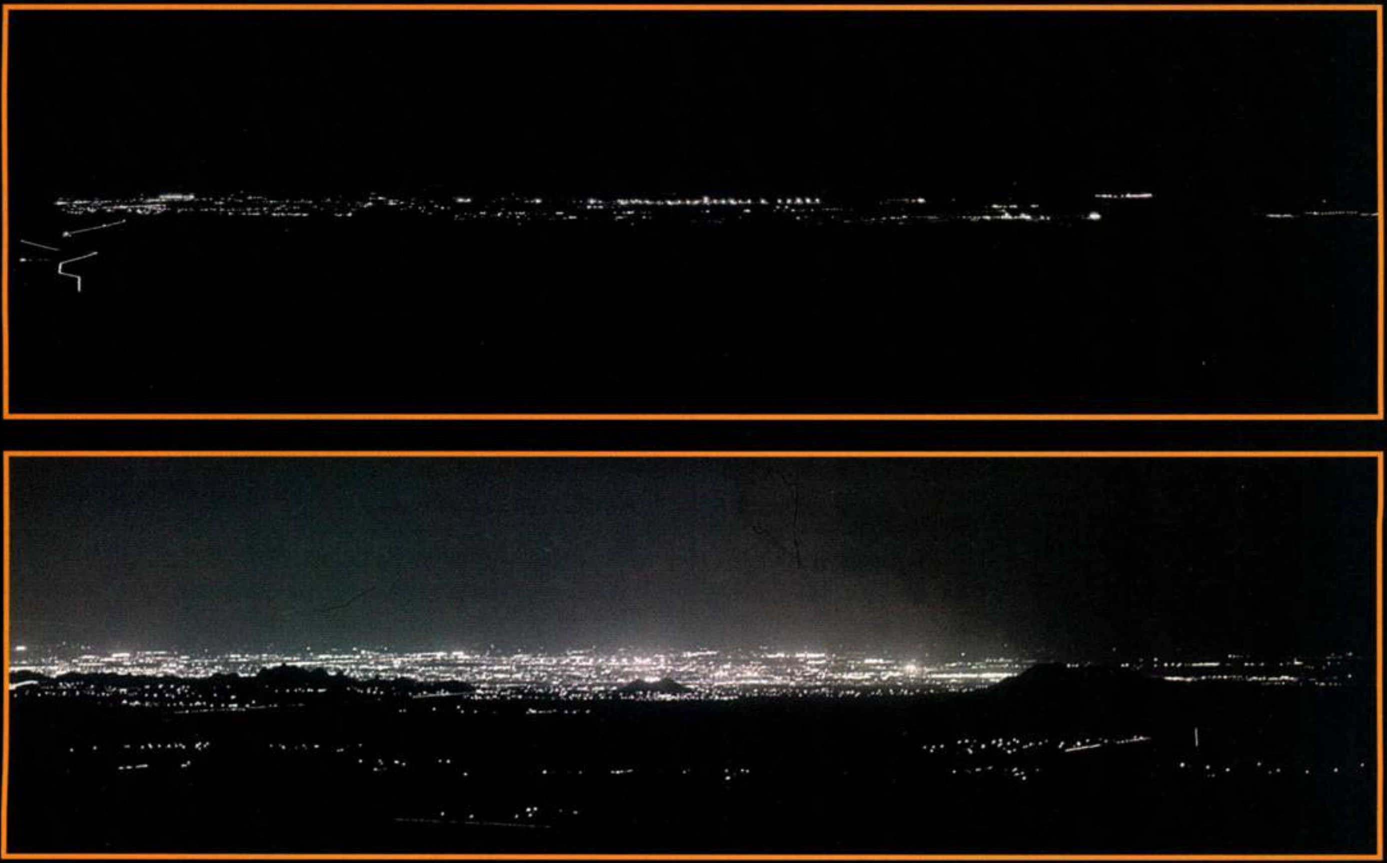
The dilemma for today's backyard astronomer is threefold: 1) What type of observing, if any, can be done at my home site?; 2) How far do I need to travel to find a reasonably dark site — or a really outstanding site?; and 3) How do I identify a good night that makes travel to these observing sites worthwhile?

## Observing from the city

You can start by checking your backyard for spots that are shielded by fences or bushes from surrounding lights. Or, take direct action by building a fence or strategically planting a few dense evergreen trees. Typically, 4th-magnitude stars are visible from the outlying suburbs of a large city. Of course it depends on local conditions, but once you find (or make) a spot that shields you from glare, the result can be surprising.

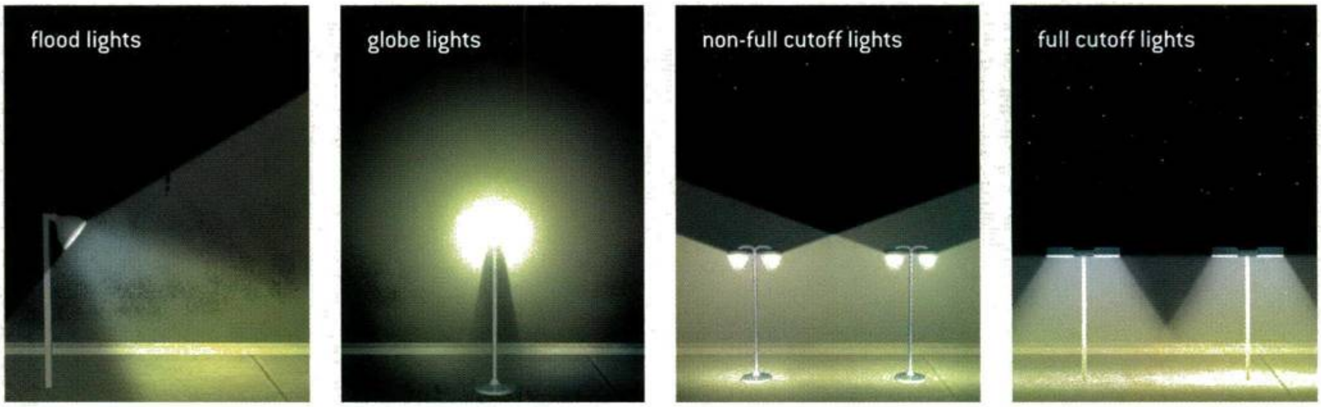
Suppose, for example, at your local observing site, you can see magnitude 4.5 stars at the zenith. This is your "limiting magnitude," often abbreviated LM. At a true "dark site," most observers can see 6th-magnitude, or even fainter, stars. What does a sky with LM = 4.5 offer? A lot. The Moon, Mars, Jupiter, and Saturn are bright enough that telescopic observations of these celestial bodies are unaffected by light pollution. And, believe it or not, an atmospheric inversion layer induced by big-city heat and pollution occasionally steadies the air so that seeing is better in town than in the country. A metropolitan view of Jupiter or Saturn shows just as much detail as a dark location, and these planets make wonderful showpiece objects for visitors to your telescope.

Other objects and events such as bright variable stars, lunar occultations, the brightest star clusters, and tracking the paths of asteroids are generally viewable from moderately light-polluted environments. Urban glow exacts a toll by brightening the field of view around the objects being viewed — the telescope's resolution is not affected. For example,

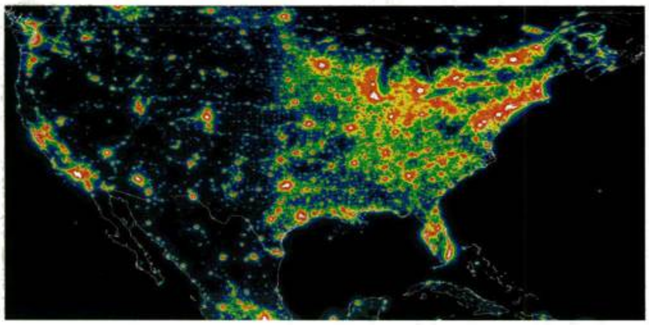


*Left,* **THE MILKY WAY,** seen in some detail, is the ultimate test of a great observing site. Beyond simply appearing milky, our galaxy's spiral arms will display a fascinating, mottled appearance from a true dark site. DOMINIC CANTIN *Above,* **TUCSON, ARIZONA** demonstrates the growth of light pollution in large cities. Compare the darker image (top) of the city in 1958 with an equivalent exposure (bottom) taken 30 years later. INTERNATIONAL DARK-SKY ASSOCIATION

### /// RATING OUTDOOR LIGHTING



**PROGRESSIVELY BETTER OUTDOOR LIGHTS** (left to right) are shown in this illustration. The best (apart from no lights at all) are those that direct the least amount of light directly into the sky. *ASTRONOMY:* ROEN KELLY



**THIS COLOR-CODED MAP** of light pollution across North America shows the darkest areas as black. These areas are generally remote and inaccessible. Gray and mauve regions are ideal hunting grounds for skies of pristine quality. They are often rural areas accessible by road. The green areas have acceptable dark sky conditions. If none of the darker areas are available to you (as will be the case in many of the northeastern states), go for the green. ISTITUTO DI SCIENZA E TECHNOLOGIA DELL'INQUINAMENTO LUMINOSO

an 8-inch telescope at a site where LM = 4 will be limited to roughly the same deep-sky targets as a 3-inch telescope under true dark skies. The resolution of the 8-inch instrument, however, is unchanged, so what you see can be studied in greater detail. The use of light pollution filters helps, but only a little. Such filters make nebulae easier to see, but they cannot transform urban skies into rural dark-site skies.

## Evaluating a local observing site

Astronomy buffs without a suitable observing site near their homes may be able to locate a suitable area within a reasonable walking or driving distance. This spot can be a "quick-look" site, one that can save the time it would take to drive to a darker site farther from home.

When inspecting a site for the first time, consider the following: Can you use your telescope in relative privacy? This is especially important if you will be easily visible to passers-by or a police patrol. If you appear to be "doing something" with a telescope, don't assume the first thing people will think of is astronomy!

Is it safe to leave your equipment unattended while you are walking to the car during setup and disassembly? If not, carry everything at once. (An observing buddy is often a fine accessory here.) A couple generations ago, the issue of personal security never came up. Today, however, safety is a paramount consideration for the lone observer.

## A remote observing site

Few people live where 6th-magnitude stars are visible from their backyards. Most amateur astronomers have to hunt for such a site, and reaching it can be an expedition if you live in or near a city of more than a million people. A 90-minute drive simply to get a reasonable view of the Milky Way has, unfortunately, become a commonplace experience.

Obstacles still exist even outside the city. More and more homeowners and businesses have installed dusk-to-dawn security lights that pump light horizontally into an observer's eye, even from a mile or more away. But beyond the aggravation of rural lighting is the question of exactly where to observe.

Stopping on an infrequently traveled rural road is fine for a quick look through binoculars, but it's less than ideal for setting up equipment that cannot be retrieved and quickly put in the car in a matter of seconds. There is a slight, but very real, danger of being mistaken for a trespasser or some form of lawbreaker (this has happened to me several times). Amateur astronomers tell horror stories about being routed by suspicious landowners (Who can blame them?) or, worse, by a carload of troublemakers on a Saturday night.

Your long-term goal should be finding a predetermined safe, dark site that is free of intruders. Begin with inquiries at a local astronomy club or ask other amateur astronomers in your area. Find out where they go for dark skies. If this doesn't work, inquire at nearby state parks or conservation areas to see if they are visited by amateur astronomers (which in itself suggests the site is good).

## The ideal site

What constitutes an ideal observing site? When the humidity is moderate to low on a moonless night in the summer and early fall, the Milky Way should be distinctly visible. Under the best conditions, the Milky Way has a textured appearance with many levels of intensity and obvious rifts. Stars should be visible to the naked eye just a few degrees above the horizon.

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**Terence Dickinson** *is the author of the beginners' guidebook* NightWatch *and co-author with Alan Dyer of the recently revised edition of* The Backyard Astronomer's Guide.

## /// RATING YOUR OBSERVING SITE

How can you evaluate an observing site? Experience is the best guide, but here is a checklist that will help you rate your site. If you use more than one site, each should be assessed separately.

- Convenience: If you can observe in comfort from your own yard, take 5 points; 3 points for a short walk; 2 for a short drive; 0 for an hour or longer drive.
- Ground level: If your site is outside a ground-level entrance where your equipment is stored, take 5 points. Take 3 points if car-loading is required, but score 0 if any full flights of stairs are involved.
- Privacy: No possibility of surprise interruptions by people, animals, or unwanted car lights is worth another 5 points. Score 0 if you sometimes feel nervous at the site.
- General light pollution: Score 10 if, on a good night, you can see magnitude 6.5 overhead, the Milky Way is obvious, and the dome of light from the nearest city bulges less than 10° above the horizon. Score 0 if you cannot see the Milky Way at all or any star fainter than magnitude 5.0. Estimate values for intermediate conditions.
- Local light pollution: This is a crucial factor. Score 0 points if you cannot avoid a local light as bright as the Full Moon. Score 4 points for a site that requires a bit of moving around to remain protected from light while observing. For a full 10 points, the brightest unobscured light should be fainter than Venus.
- Horizon: A clear, flat horizon to the south earns 5 points. Southern obstructions higher than 30° rate just 2 points. Similar obstructions in all directions score 0.
- Insects: Mosquitoes are the enemy. Subtract up to 5 points if they are predictably annoying for more than one month each year.
- Snow: Snow cover has no redeeming value in astronomy. Apart from the cold weather that accompanies it, snow reflects light and increases overall light pollution. Subtract 1 point for each month of likely snow cover at the observing site.

Maximum possible score (for a site next to your home, at a perfectly dark location, with little chance of mosquitoes or snow) is 40 points. Any score over 20 should be considered perfectly acceptable for regular use.

**THE IDEAL OBSERVING SITE** in North America may be Lowell Observatory's Anderson Mesa site. It boasts low humidity, moderately high altitude, and true dark skies. LOWELL OBSERVATORY

That's the ideal, but it's rare not to have at least one dome of light somewhere on the horizon. If it's cloudy when you visit a potentially good site, light pollution from surrounding towns and cities will illuminate the clouds. If the largest dome of light is northward, it will be least annoying. Objects there will be visible near the zenith two seasons later.

The specific terrain of the observing site can influence sky conditions as well. Hilltop sites may sound ideal, but wind can be a frequent unwelcome companion. Wind-blown dust, in particular, is a scourge that is best avoided. Snow cover is probably the worst situation, not just because it is cold, but also because it reflects light. Even if there is little light pollution, the starry sky itself still illuminates the ground. When that light is reflected off snow (and back toward its source), it doubly illuminates moisture and dust particles in the atmosphere.

The ideal dark site is a clearing with fairly heavy vegetation nearby such as dense grass, scrub shrubbery, or trees (or a combination of these). Coniferous vegetation is preferable to leafy trees because the former releases less moisture into the atmosphere. A further advantage is the skylight-absorbing qualities of dark vegetation. A thick ground cover also acts as an insulating blanket, slowly releasing the ground's heat at night and shielding it from the Sun during the day.

## Factors affecting all dark sites

No matter where you are on Earth, the night sky has a natural brightness that becomes obvious to fully dark-adapted eyes. Three sources cause this glow: 1) Zodiacal light — sunlight reflected off dust particles near the plane of the solar system; 2) the atmosphere's permanent low-level auroral glow; and 3) illumination of Earth's atmosphere by starlight. Natural sky glow is a given — it's always there.

In addition to natural sky glow, particles in the air scatter and absorb light from celestial objects. Chief among these particles are dust and water vapor. Illumination of the particles by ground-based sources of light pollution accounts for most of the glow so familiar at the average observing site. But even if there were no light pollution, light absorption by air amounts to at least 0.3 magnitude at a site near sea level, and 0.15 magnitude at 7,000 feet. A typical site in the eastern United States loses at least another 0.2 magnitude to extinction due to higher average humidity compared to arid sites.

At superb sites, such as the best observatory locations in the Southwestern United States, all the factors listed above add up to a loss of one-third to one-half magnitude compared to observing from, say, the space shuttle. Astronomer-astronauts who have made careful visual comparisons have confirmed this. Even so, there are many locations where experienced observers (whose feet remain firmly on the ground) can also confirm that the few legendary sites don't have a monopoly on the great skies. The key is avoiding light pollution.

## Finally, which night?

Now that you have your site, the last part of your quest is choosing a good night for your observing trek. The Moon's phase is important, of course, but I'm speaking of weather. Fortunately, a service called the Clear Sky Clock is available for North American observers from Alan Rahill of Environment Canada in collaboration with software guru Attilla Danko of Ottawa, Ontario. The Clear Sky Clock takes a lot of the guesswork out of determining in advance if your observing site will be clear.

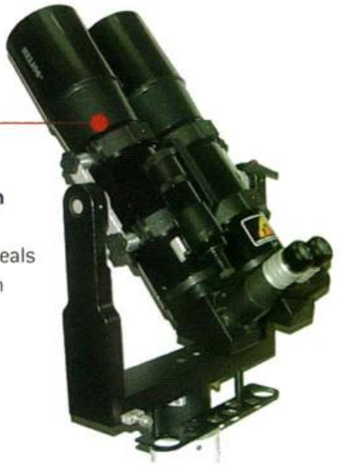
Start by clicking your site's location on the map of North America at www.cleardarksky.com/csk. Then click the nearest named site to your location (there are more than 1,200). The web page provides all the necessary information for you to fully interpret the Clock and provide a forecast for your local area. I have found it about 80 percent accurate. Unlike local weather forecasts, this is a specialized service for observers. ■

# 25 hot new pro

From giant binoculars to computer-controlled telescopes to helpful accessories, here's a double dozen to delight observers.

/// BY PHIL HARRINGTON

**APOGEE'S 25x100 BINOCULARS** fall within the "giant" binocular category due to the pair of high-quality 4-inch objective lenses.



**THE HELIOS 150mm BINOSCOPE** by Astromeccanica reveals the universe to both your eyes at once.

**THE ASTROTECH SCOPIC 300** is a "telescoping" telescope with a collapsible tube for easy storage and transportation.

The last year or so has seen a wave of new telescopes, eyepieces, and accessories for backyard stargazers. Every observer probably has his or her own favorites, but here's our top 25. Each stands above the crowd and offers more enjoyment for the time we spend under the stars. The list is divided into three groups, arranged alphabetically by brand name: binoculars and telescopes, cool gadgets, and eyepieces and filters.

## BINOCULARS AND TELESCOPES

### Apogee 25x100 binoculars

Giant binoculars are more popular than ever. The main reason is their availability at prices that would have been unheard of a few years ago. One of the best buys is the Apogee 25x100 giant binoculars. For $350, you get what amounts to a pair of 4-inch refracting telescopes that comes with multicoated objectives and high-quality (BaK-4) prisms. Also included with the binoculars are a tripod adapter and carrying case.

### Astromeccanica Helios 150mm Binoscope

Italian manufacturer Astromeccanica mates two identical refracting telescopes from other companies to create some of the most robust binocular instruments in the world. Astromeccanica replaces the original focusers with a mirror/prism assembly and joins the tubes in a sturdy cradle that holds both instruments parallel. The focuser accommodates 1¼" eyepieces. The assembly is held by a sturdy, alt-azimuth fork mount on a pier.

Oberwerk of Xenia, Ohio, imports two of Astromeccanica's binoscopes, including the 6-inch f/8 Helios 150 featured here. When used at low power, the Astromeccanica 150 Binoscope is unequaled for examining star-filled Milky Way fields. At higher magnifications, it serves well for viewing the Moon and planets.

### Astrotech Scopic 300 telescoping reflector

All telescope users share the problem of where to store the telescope when it's not in use. No longer. The 12-inch f/5 Scopic is a

# ducts

"telescoping telescope" from Italy on a Dobsonian mount. The trick is its two-piece tube. Pull up on the front of the tube and each segment slides out on guide rails, locking in place with spring-loaded clips. Setup takes less than a minute and requires no tools. The precise fit of the tube segments holds optical collimation very well. When open, the Astrotech Scopic 300 measures 17 inches by 18 inches by 62 inches high, but collapses to a height of only 28 inches. The helical focuser (by Borg Telescopes) accepts 2" eyepieces.

### Celestron Advanced Series computerized telescopes

To address concerns about stability, vibration damping time, and usability in moderate wind conditions, Celestron has added 2-inch tubular steel legs to their CG-5 German equatorial mount. The stiffer legs, coupled with dual-axis go-to control has resulted in a new Advanced Series Computerized telescope line. Designed for serious beginning and intermediate skywatchers, the line includes a 6-inch f/8 refractor; 8-inch f/5 and 10-inch f/4.7 Newtonian reflectors; and 5-inch f/10, 8-inch f/10, and 9¼-inch f/10 Schmidt-Cassegrains. The computerized Advanced Series CG-5 mount, with its 40,000-object database, is also sold separately for anyone interested in updating an existing telescope.

### Celestron CGE Schmidt-Cassegrain telescopes

Celestron's new line of CGE instruments couples their four best-selling Schmidt-Cassegrain telescope optical tube assemblies with computerized German equatorial mounts. The resulting creations are the 8-inch f/10 CGE 800, the 9¼-inch f/10 CGE 925, the 11-inch f/10 CGE 1100, and the 14-inch f/11 CGE 1400 (pictured here). Although heavier than fork mounts, well-made German equatorials like the CGE are more stable for visual and photographic observations. The CGE mount is outfitted with Celestron's NexStar go-to system.

### Celestron NexStar 9¼ GPS Schmidt-Cassegrain telescope

In addition to Celestron's CGE 9¼ mentioned above, this telescope is now available on a state-of-the-art fork mount as the NexStar 9¼ GPS. Featuring a carbon-fiber tube, the 9¼ GPS

**CELESTRON'S C5-SGT** is part of its Advanced Series telescope line, which was designed with serious beginning and intermediate observers in mind.

**THE 14-INCH F/11 CGE 1400** by Celestron is the largest telescope in the CGE line, which includes 8-inch, 9¼-inch, and 11-inch models, all f/10.

**CELESTRON'S NEXSTAR 9¼ GPS** comes with a carbon-fiber tube mounted on a state-of-the-art fork mount.

comes mounted solidly on the NexStar 11's fork mount. Like the NexStar 8 and 11 GPS models, the 9¼ includes a programmed database that includes more than 40,000 objects, an adjustable heavy-duty tripod, and an integral hand controller that stores in one of the fork arms.

**DGM OPTICS' OA-3.6 ATS** incorporates an off-axis design to provide unobstructed views comparable to high-end apochromatic refractors.

## DGM Optics OA-3.6 ATS reflector

Apochromatic refractors generally produce the sharpest, highest contrast images of any amateur telescope. That perfection, however, comes with a hefty price tag. Wouldn't it be great if you could buy a telescope that enjoyed the same optical perfection, but at a more down-to-earth price?

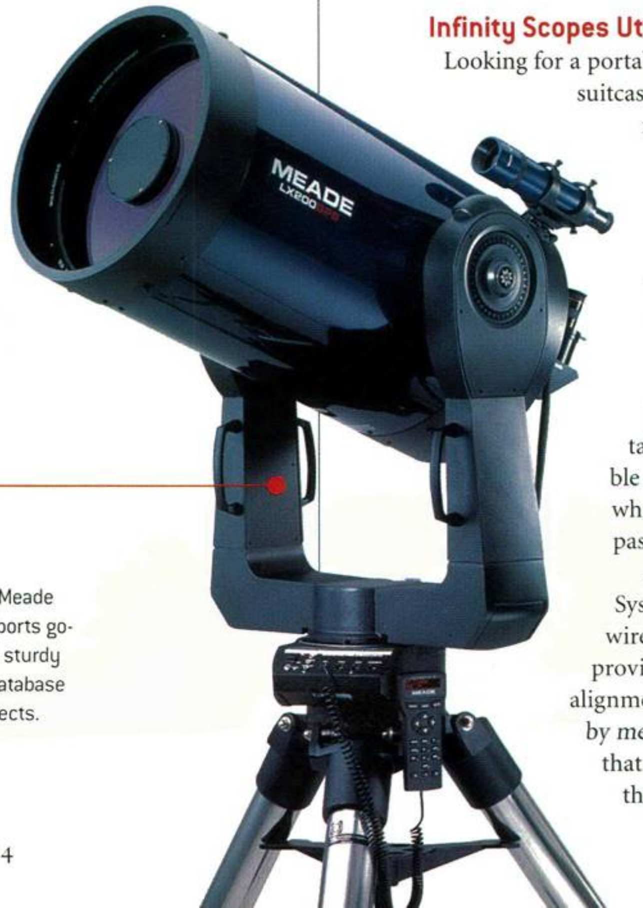
Enter the OA-3.6 ATS, the smallest of seven off-axis reflecting telescopes with Dobsonian mountings sold by DGM Optics. A conventional Newtonian reflector centers its secondary mirror in the telescope's aperture, interrupting the light path and causing a loss in image contrast. Using an off-center primary mirror with a long f/ratio, DGM's reflectors reduce the secondary's size and move it out of the way for an unobstructed view. The result is a reflector that delivers images like a top-end refractor, but at a fraction of the cost.

**THE 20-INCH TRUSS DESIGN REFLECTOR** by Discovery Telescopes will cure aperture fever in almost all cases. A 24-inch model is also available.

## Discovery Telescopes 20-inch and 24-inch Truss Design reflectors

Well known among amateurs for a wide variety of Newtonian reflectors perched atop Dobsonian mounts, Discovery Telescopes recently expanded its range of apertures. Its Truss Design (TD) instruments now feature 20-inch reflectors (f/4, f/4.375, and f/5) as well as its biggest, a 24-inch f/5. Like the smaller models, all mirrors are made in its Oceanside, California, plant. Optical quality is very good, as is each mounting's woodwork.

**INFINITY SCOPES'S Uti8** is an 8-inch f/4.5 travelscope that comes with its own suitcase.



**THE 14-INCH LX200GPS** by Meade Instruments sports go-to capability, a sturdy tripod, and a database of 145,000 objects.

## Infinity Scopes Uti8 Travelscope reflector

Looking for a portable telescope that comes with its own suitcase, ready for a road trip at a moment's notice? Consider the Uti8 from Infinity Telescopes. The Uti is an 8-inch f/4.5 Newtonian reflector with a Dobsonian-style alt-azimuth mount raised on a low tripod. Infinity uses carbon fiber and anodized aluminum components to create a telescope that is good looking and solidly made. Uti's open-truss tube and mount take less than three minutes to assemble from the hardshell carrying case, which fits into the overhead rack of a passenger jet.

A Windows-based "Celestial Viewing System" is also available to couple Uti wirelessly to a Palm Pilot. The software provides routines for mounting alignment and for finding celestial objects by means of an LED targeting system that tells you what direction to move the telescope.

### Meade Instruments 14-inch f/10 LX200GPS Schmidt-Cassegrain telescope

First introduced in 1992, Meade's line of LX200 telescopes has become the benchmark for all computer-driven Schmidt-Cassegrain instruments. More recently, second-generation LX200GPS models, which range between 8 and 12 inches, now feature computer-controlled fork mounts that automatically configure themselves using data from global positioning satellites.

Earlier this year, responding to requests from amateur astronomers, Meade added a 14-inch f/10 instrument to the LX200GPS line. The 14-inch LX200GPS enjoys the same features found on the smaller models. After the telescope is set up, you can select a target from its built-in listing of more than 145,000 objects. Then, simply press the go-to button and the LX200GPS will automatically center the object.

### Orion Telescopes Atlas reflectors

A year ago, backyard astronomers were hard-pressed to find a Newtonian reflector on a heavy-duty equatorial mount. Now, thanks to Orion Telescopes, we can choose from two. The Atlas line of Newtonians includes 8-inch f/5 and 10-inch f/4.7 optical tube assemblies, each mounted on a sturdy Atlas German equatorial mount. Both telescopes feature 2" focusers, 9x50 finder scopes, and variable-speed, dual-axis drive motors. Each attaches to its mount with a sliding dovetail plate for easy balancing. Add Orion's optional 80mm guide scope and you have an astrophotography rig that's ready to roll.

### Orion Telescopes Funscope 76 reflector

Recently, Orion Telescopes introduced what might well be the perfect telescope for new astronomers between the ages of six and nine, an audience that most other companies really don't address. The Funscope 76 is built around a 3-inch f/3.7 parabolic primary mirror housed inside a hard plastic "spaceship" that strongly resembles the larger-aperture Astroscan from Edmund Scientific, Inc. The telescope weighs less than three pounds and measures only 12 inches long. The hinged nose cone of the spaceship caps the open-ended tube to keep dust (as well as crayons, bugs, and peanut butter) off the mirror. While its images obtained with the Funscope 76 won't compete with more expensive instruments, they are certainly good enough to entertain a child who later will grow into a bigger telescope.

### Orion Telescopes SkyView Pro 6LT reflector

For years, when backyard astronomers pondered the purchase of their first serious telescope, the classic answer would be a 6-inch f/8 Newtonian reflector on a German equatorial mount. The 48-inch focal length of such an instrument is a great choice for an all-around telescope. It's adept at deep-sky viewing and planet watching, while its 6-inch aperture can show all the Messier objects plus scores of other sky favorites.

Orion Telescopes has introduced a new version of this perennial favorite, the SkyView Pro 6LT (for "long tube"). The 6LT comes with a 6x30 finder scope, two eyepieces, a 1¼" focuser, and the SkyView German equatorial mount and tripod — everything someone starting out in astronomy needs for years of viewing pleasure.

ORION
Atlas

**ORION TELESCOPES' ATLAS 8 REFLECTOR** comes with a sturdy German equatorial mount that facilitates visual observing or imaging.

**THE WHIMSICAL FUNSCOPE 76** by Orion Telescopes is a perfect first telescope for young skygazers.

**THE SKYVIEW PRO 6LT** by Orion Telescopes, with its German equatorial mount, is a great all-around telescope.

SOLARSCOPE Ltd
ISLE OF MAN
SOLARVIEW 50

**THE SOLARVIEW-50** hydrogen-alpha solar telescope by Solarscope isolates a specific spectral line to show the Sun's chromosphere and prominences.

**STELLARVUE'S SV80** apochromatic refractor with a three-element fluorite objective is available in two focal ratios: f/6 and f/7.5.

**THE 10-INCH F/7 PLANET KILLER** by Teeter's Telescopes is a Dobsonian-mounted open-truss design that incorporates a small secondary mirror to improve image contrast.

### Solarscope SolarView-50 hydrogen-alpha refractor

Dedicated Sun worshippers will be interested in the 2-inch f/8 SolarView-50 refractor from Solarscope, Ltd. Ordinary solar filters show the Sun across the whole visible spectrum. The SolarView-50 uses a Fabry-Perot etalon, an optical device tuned to "see" only a single wavelength of light: 656.28 nanometers, better known as the hydrogen-alpha (H$\alpha$) line. The small amount of sunlight that passes through allows study of the Sun's chromosphere as well as great views of prominences. Unlike many other solar scopes, the SolarView-50's etalon offers a completely unobstructed view, greatly improving image contrast.

### Stellarvue SV80 APO refractor

If you are looking for a high quality, high-contrast telescope you can carry outside with one hand, the new Stellarvue SV80 APO just might be your baby. The SV80 APO is an altered version of Stellarvue's popular 80mm AT1010 shorty refractor. The SV80 APO differs from the AT1010 due to the fact that it employs a 3-element, fluorite objective.

Two models of the SV80, an f/6 and an f/7.5, give skygazers the choice between a small, grab-and-go wide-field instrument or a slightly longer telescope geared more toward lunar and planetary observing. Each version includes a 2" focuser from Feathertouch, tripod mounting rings, a red-dot 1x finder, and an aluminum carrying case perfect for airline travel.

### Teeter's Telescopes 10-inch f/7 Planet Killer reflector

With the great 2003 apparition of Mars still fresh in mind, observers have a renewed interest in planet-watching. Many believe that a refractor makes the best planetary instrument. Yet, an optimized reflector can do just as well when trained on the planets, and for less money.

Consider the Planet Killer reflector from Teeter's Telescopes. This interestingly-named instrument is an open-truss Newtonian on a Dobsonian mounting. Rather than use faster f/ratio mirrors like most Dobsonians, Rob Teeter prefers primary mirrors in the

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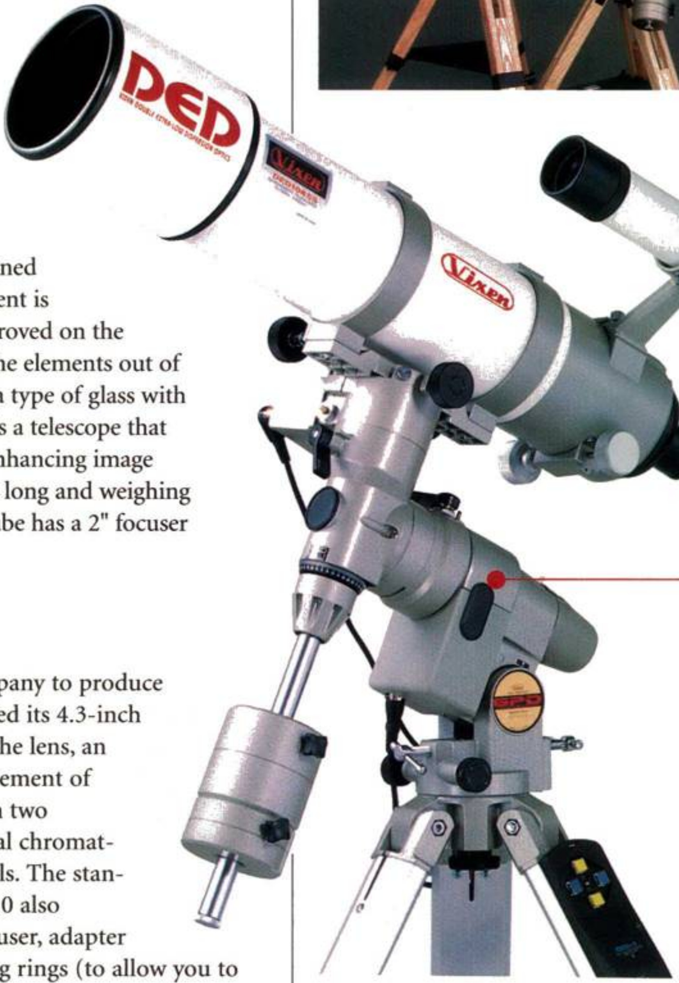
**Phil Harrington** *is a contributing editor for* Astronomy *and the author of several books, including* Star Ware, *a guide to astronomy equipment.*

f/7 to f/8 range. That focal ratio, combined with low-profile focusers, keeps the size of the secondary mirror to an absolute minimum, thereby maximizing image contrast. Combine high contrast with a large aperture and you have a "killer" telescope for the planets, as well as most deep-sky objects. Most amateur astronomers will need a step-stool to get to the eyepiece — especially when the object being observed is near the zenith — but the view is worth the trip.

**TELE VUE'S NP-127** is a 5-inch f/5.2 apochromatic refractor with a four-element (Petzval) objective.

## Tele Vue NP-127 refractor

Few would deny that Al Nagler's Tele Vue Optics, Inc. has revolutionized the equipment used in amateur astronomy. This past year, Tele Vue did it again when they introduced the 5-inch f/5.2 NP-127 apochromatic refractor. The heart of the NP-127 is a four-element objective with lenses combined in two groups. Such an optical arrangement is known as a Petzval objective. Nagler improved on the classic Petzval design by making one of the elements out of fluorite and two of the other three from a type of glass with special dispersion properties. The result is a telescope that completely suppresses false color while enhancing image contrast and clarity. Measuring 33 inches long and weighing 14 pounds, the NP-127's ivory-colored tube has a 2" focuser and a sliding dew shield.



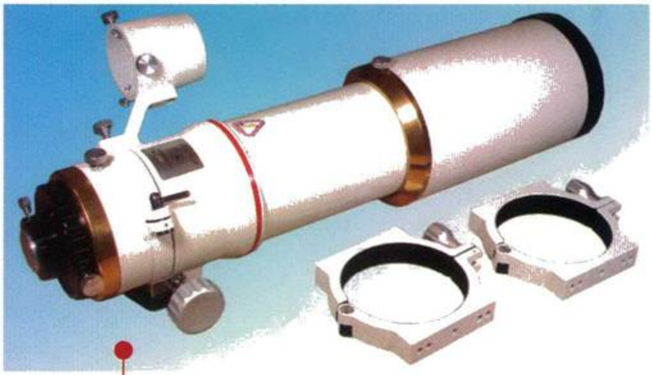
**THE WILLIAM OPTICS FLUORO-STAR FLT-110** is a 4.3-inch f/6.5 apochromatic refractor with a 4-inch focuser.

## William Optics Fluoro-Star FLT-110 refractor

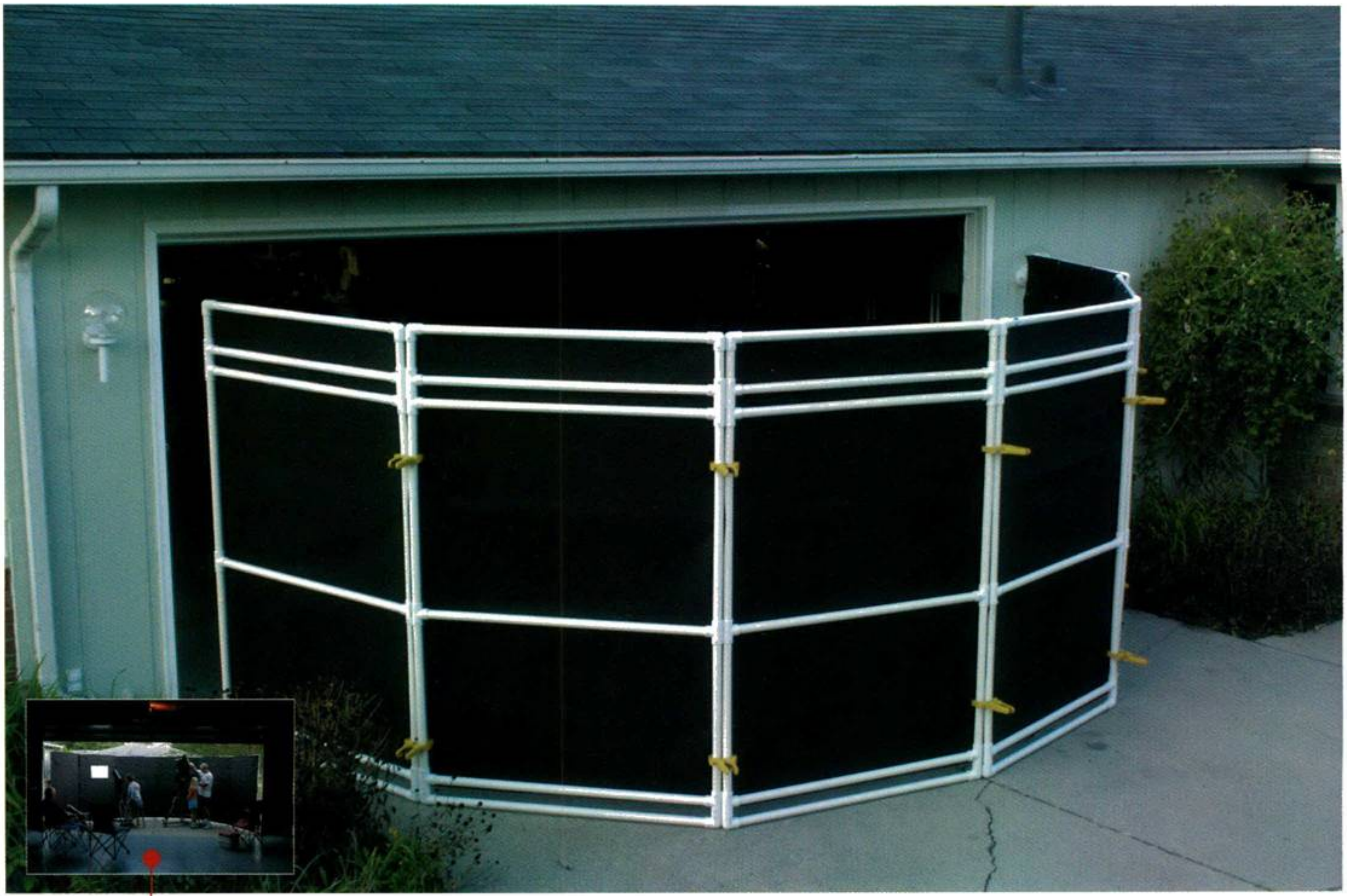
William Optics, the first Taiwanese company to produce apochromatic refractors, recently unveiled its 4.3-inch f/6.5 Fluoro-Star FLT-110 instrument. The lens, an oil-spaced triplet that sandwiches one element of super-low dispersion (SD) glass between two crown-glass elements, suppresses residual chromatic aberration to nearly undetectable levels. The standard package for the Fluoro-Star FLT-110 also includes a 4-inch diameter rotatable focuser, adapter rings for 1¼" and 2" eyepieces, mounting rings (to allow you to couple the optical tube assembly to your favorite mount), a rotatable finder bracket (a very nice feature), a sliding dew cap, and an aluminum carrying case. Optional accessories include a wide range of field flatteners and adapters for 35mm, medium-format and digital cameras, and video photography, too.

## Vixen DED 108SS refractor

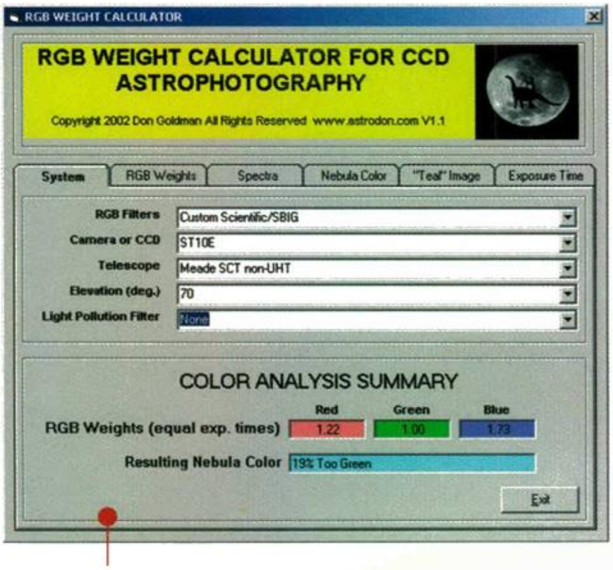
The 4.3-inch f/5 DED 108SS is Vixen Optical's top astrophotographic telescope. The four-element objective, which includes two extra-low dispersion (ED) lenses, is organized into three groups to deliver crisp images of celestial objects, free of false color, across the entire field of view. Thanks to its 90 millimeter diameter photographic field, the DED 108SS is perfect for photography using both 35mm and medium-format cameras. Of course, you can use the DED 108SS for visual observations as well. Mounting rings are included so you can select any mount for the optical tube assembly, but if you fit the tube on Vixen's GP-DX mount, you will be impressed with the result.



**THE VIXEN DED 108SS** is a 4.3-inch f/5 refractor that incorporates a four-element objective to provide a wide field of view for astrophotography.



**THE PORTABLE PANEL OBSERVATORY** by Dark Sky, Inc. is an opaque framework of PVC piping and sheets that will shield your telescope from ambient light.



RGB WEIGHT CALCULATOR

RGB WEIGHT CALCULATOR FOR CCD ASTROPHOTOGRAPHY

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RGB Filters: Custom Scientific/SBIG

Camera or CCD: ST10E

Telescope: Meade SCT non-UHT

Elevation (deg.): 70

Light Pollution Filter: None

COLOR ANALYSIS SUMMARY

| | Red | Green | Blue |
|---|---|---|---|
| RGB Weights (equal exp. times) | 1.22 | 1.00 | 1.73 |

Resulting Nebula Color: 19% Too Green

**DON GOLDMAN'S *RGB WEIGHT CALCULATOR*** is not a new diet fad, but rather a software package that calculates the time ratio necessary for CCD exposures through color filters.

**COOL GADGETS**

## Dark Sky Portable Panel Observatory

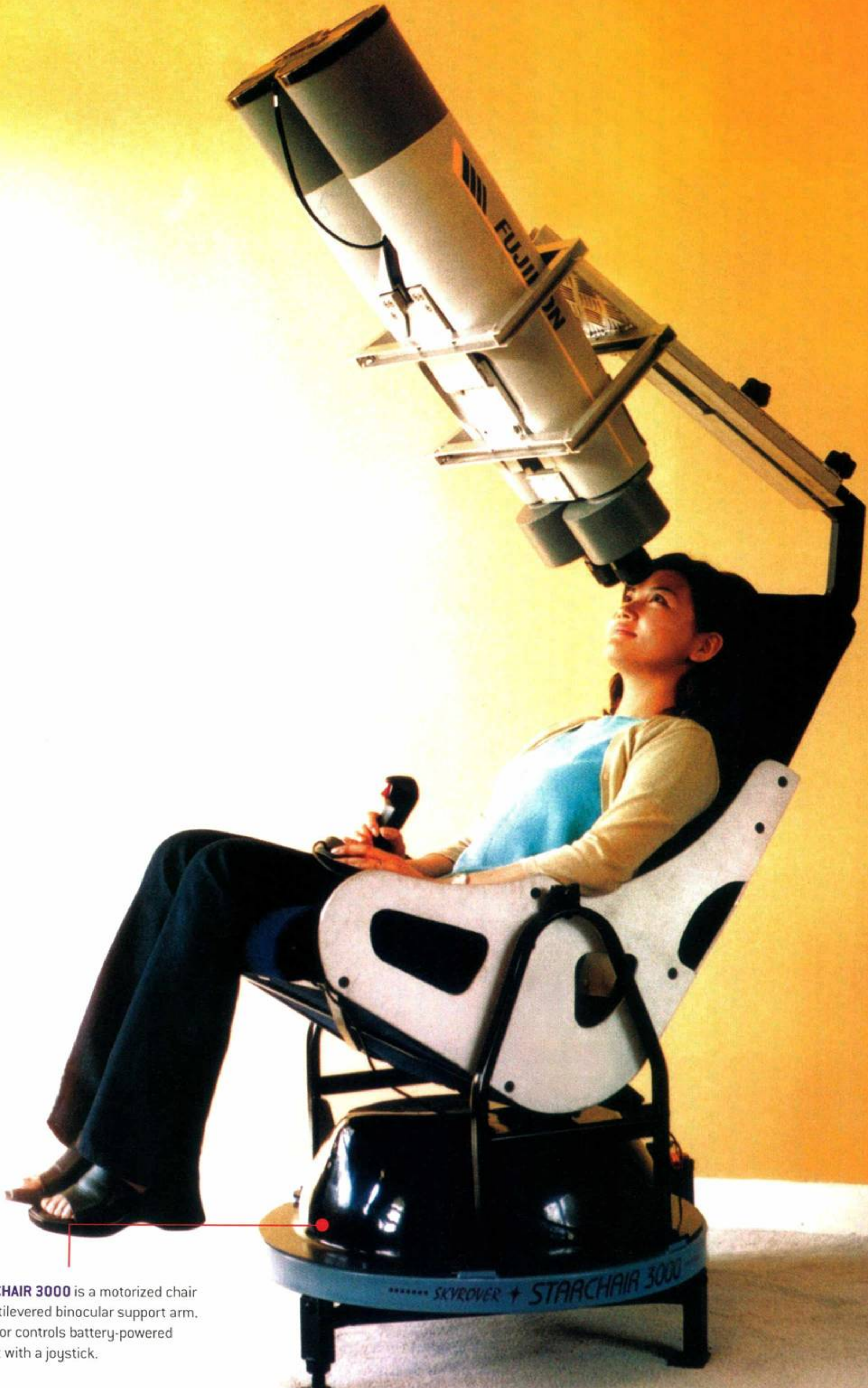
For times when you can't escape to a dark-sky site, Dark Sky, Inc. offers a solution called a Dark Sky Portable Panel Observatory. It consists of a framework of PVC piping and sheets of opaque canvas that shield your telescope from ambient light. The panels each measure 63 inches tall and 48 inches wide and attach to one another using ratcheting clamps. The standard kit includes four panels, while the "star party" set comes with six. Riser kits are also available for extending panel height by either 12 inches or 22 inches, and "windy night" kits include stakes and tie-downs.

## Don Goldman's *RGB Weight Calculator* software

Nearly all CCD cameras are monochromatic, so creating a color image requires exposures through red, green, and blue filters. A problem astrophotographers face is calculating the length of each exposure. Rather than experimenting, Don Goldman developed a Windows-based program called *RGB Weight Calculator*. Taking into account the color filters, CCD camera, and telescope, the program calculates the time ratio necessary for each exposure.

## Starchair 3000

What would happen if you combined giant binoculars, a video game, and an amusement-park ride? You'd get the Starchair 3000. While most binocular mounts use a counterweighted parallelogram frame, the Starchair 3000 is different. The Starchair is a motorized chair with a binocular-support arm that is strong enough to hold even heavy binoculars. Using a variable-speed joystick, an observer


FUJINON
SKYROVER ✦ STARCHAIR 3000

**THE STARCHAIR 3000** is a motorized chair with a cantilevered binocular support arm. The operator controls battery-powered movement with a joystick.

## /// PRICING AND CONTACT INFORMATION

**APOGEE 25x100 BINOCULARS**
$350
Apogee, Inc., P. O. Box 136
Union, IL 60180
[t] 877.923.1602 or 815.568.2880
[w] www.apogeeinc.com

**ASTROMECCANICA HELIOS 150mm BINOSCOPE**
$7,295
Oberwerk Corporation, 2440 Wildwood
Xenia, OH 45385
[t] 866.244.2460
[w] www.bigbinoculars.com

**ASTROTECH SCOPIC 300**
3,470 Euros (about $3,780)
Astrotech s.r.l., Via Marconi 27
30027 San Donà di Piave (VE), Italy
[t] (011) 39.421.222179
[w] www.astrotech.it/basic/prodotti/scopic/scopic.htm

**CELESTRON ADVANCED SERIES COMPUTERIZED TELESCOPES**
C5-SGT (5-inch f/10 SCT): $1,099; C6-RGT (6-inch f/8 refractor): $999; C8-NGT (8-inch f/5 reflector): $949; C8-SGT (8-inch f/10 SCT): $1,299; C9¼ SGT (9¼-inch f/10 SCT): $1,699; C10 NGT (10-inch f/4.7 reflector): $1,149; CG-5 Advanced Series Go-to Equatorial Mount: $675
Celestron International, 2835 Columbia St.
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com

**CELESTRON CGE SCHMIDT-CASSEGRAIN TELESCOPES**
CGE 800 (8-inch f/10 SCT): $3,499; CGE 925 (9¼-inch f/10 SCT): $3,799; CGE 1100 (11-inch f/10 SCT): $4,149; CGE 1400 (14-inch f/10 SCT): $5,799
Celestron International, 2835 Columbia St.
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com

**CELESTRON NEXSTAR 9¼ GPS**
$2,699
Celestron International, 2835 Columbia St.
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com

**DARK SKY PORTABLE PANEL OBSERVATORY**
Standard panel kit: $300; Star party kit: $400
Dark Sky, Inc., 3605 E. Saddle Dr.
Fort Wayne, IN 46804
[t] 877.327.5759
[w] www.darkskystuff.com

**DGM OPTICS OA-3.6 ATS**
$875
DGM Optics, P. O. Box 120
Westminster, MA 01473
[t] 978.874.2985
[w] www.dgmoptics.com

**DISCOVERY TELESCOPES 20-INCH AND 24-INCH TRUSS DESIGN REFLECTORS**
20-inch (f/5): $5,495; 24-inch (f/5): $8,999
Discovery Telescopes, 615 South Tremont St.
Oceanside, CA 92054
[t] 760.967.6598
[w] www.discovery-telescopes.com

**DON GOLDMAN'S *RGB WEIGHT CALCULATOR***
$39.95
Don Goldman, 9224 Mott Court
Orangevale, CA 95662
[w] www.astrodon.com

**INFINITY SCOPES Uti8 TRAVELSCOPE**
$2,295
Infinity Scopes, P. O. Box 69207
Tucson, AZ 85737
[t] 520.248.0932
[w] www.infinityscopes.com

**MEADE INSTRUMENTS 14-INCH f/10 LX200GPS**
$4,295 ($4,645 with UHTC coatings)
Meade Instruments, 6001 Oak Canyon
Irvine, CA 92620
[t] 800.626.3233 or 949.451.1450
[w] www.meade.com

**ORION TELESCOPES ATLAS 8 AND 10 REFLECTORS**
$1,099 and $1,299
Orion Telescopes and Binoculars, P. O. Box 1815
Santa Cruz, CA 95061
[t] 800.447.1001
[w] www.telescope.com

**ORION TELESCOPES FUNSCOPE 76**
$89.95
Orion Telescopes and Binoculars, P. O. Box 1815
Santa Cruz, CA 95061
[t] 800.447.1001
[w] www.telescope.com

**ORION TELESCOPES SKYVIEW PRO 6LT**
$469
Orion Telescopes and Binoculars, P. O. Box 1815
Santa Cruz, CA 95061
[t] 800.447.1001
[w] www.telescope.com

**SOLARSCOPE SOLARVIEW-50 HYDROGEN-ALPHA TELESCOPE**
$4,299
Kendrick Astro Instruments
2920 Dundas Street West
Toronto, ON M6P 1Y8 Canada
[t] 800.393.5456
[w] www.kendrick-ai.com

**STARCHAIR 3000**
$3,950
Starchair Engineering, Ltd., 1 First Street
Gawler, South Australia, 5118, Australia
[t] (011) 618.8522.7272
[w] www.starchair.com

**STELLARVUE SV80 APO**
$1,795 (f/6 and f/7.5)
Stellarvue, 11808 Kemper Road
Auburn, CA 95603
[t] 530.823.7796
[w] www.stellarvue.com

**TEETER'S TELESCOPES 10-INCH f/7 PLANET KILLER**
$2,350
Teeter's Telescopes
2 Utica Court
Jackson, NJ 08527
[t] 732.901.8435
[w] www.teeterstelescopes.com

**TELE VUE NP-127**
$5,975
Tele Vue Optics, 32 Elkay Dr.
Chester, NY 10918
[t] 845.469.4551
[w] www.televue.com

**TELE VUE NAGLER 2.5mm, 3.5mm, AND 11mm TYPE 6 EYEPIECES**
2.5mm Nagler T6: $280; 3.5mm Nagler T6: $280; 11mm Nagler T6: $280
Tele Vue Optics, 32 Elkay Dr.
Chester, NY 10918
[t] 845.469.4551
[w] www.televue.com

**TELE VUE 41mm PANOPTIC EYEPIECE**
$495
Tele Vue Optics, 32 Elkay Dr.
Chester, NY 10918
[t] 845.469.4551
[w] www.televue.com

**TELE VUE BANDMATE FILTERS**
UHC: $125 (1¼"), $215 (2"); OIII: $125 (1¼"), $215 (2")
Tele Vue Optics, 32 Elkay Dr.
Chester, NY 10918
[t] 845.469.4551
[w] www.televue.com

**VIXEN DED 108SS**
$3,400 (tube only); $4,800 (on GP-DX mount)
Vixen North America, 32 Elkay Dr.
Chester, NY 10918
[t] 845.469.8660
[w] www.vixenamerica.com

**WILLIAM OPTICS FLUORO-STAR FLT-110**
$2,995
William Optics, 4200 Avenida Sevilla
Cypress, CA 90630
[t] 714.209.0388
[w] www.william-optics.com

controls the chair's up/down and left/right motions to aim the binoculars. The Starchair is powered by a 12-volt automobile battery.

**EYEPIECES AND FILTERS**

### Tele Vue Nagler 2.5mm, 3.5mm, and 11mm Type 6 eyepieces

Asked to list their favorite eyepieces, many veteran observers include one or more Naglers from Tele Vue. The original Nagler eyepieces transformed the market with their huge fields of view. But they were large and heavy.

Continuing to improve on the design, Tele Vue introduced four compact Type 6 Naglers in 2002. With focal lengths ranging from 5mm to 13mm, all eyepieces squeeze seven lens elements into 1¼" diameter barrels. But don't let their small size fool you. They still enjoy the same 82° apparent field of view as other Naglers, but with even better eye relief and image contrast.

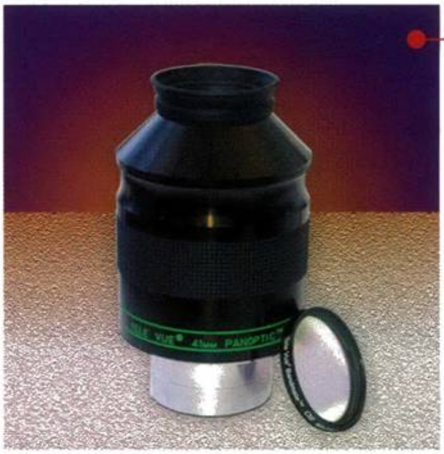
In 2003, three new focal lengths joined the ranks: 2.5mm, 3.5mm, and 11mm, ideal for medium- and high-power uses. Like other Type 6 models, each of the new focal lengths also has 12mm of eye relief for comfortable viewing.

ue® 11mm Nagler
Tele Vue® 3.5mm
®2.5mm Nagler™

**NEW TELE VUE NAGLER TYPE 6 EYEPIECES** come in 2.5mm, 3.5mm, and 11mm focal lengths.

### Tele Vue 41mm Panoptic eyepiece

The 24mm Panoptic eyepiece that Tele Vue introduced in 2002 was heralded for delivering the widest possible field of view in a 1¼" format. Tele Vue carries that approach a step further with the new 41mm Panoptic eyepiece. It produces the widest real field of view possible in a 2" eyepiece. With a 68° apparent field of view and 27mm of eye relief, this eyepiece is especially suited for telescopes with focal ratios of f/6 and higher, such as Schmidt-Cassegrains and Maksutovs. The 41mm Panoptic includes a flexible eyecup for comfortable viewing, as well as a scalloped and knurled barrel that's easy to grab, even with gloves on.



**TELE VUE'S 41MM PANOPTIC** eyepiece produces the widest field of view possible in a 2" eyepiece.

### Tele Vue Bandmate filters

Dim nebulae test an observer's skill. Skyglow often obscures much of a nebula's detail. That's why most deep-sky observers, even those who trek out to the dark hinterlands, use special filters to isolate the nebula from the surrounding sky.

Tele Vue's ultra-high contrast (UHC) and oxygen-III (OIII) filters, called Bandmates, can help with this problem. The filters admit light emitted by nebulae while blocking most skyglow. Bandmates can be purchased to fit either 1¼" or 2" eyepieces.

Tele Vue® Bandmate™ OIII s/n 1000

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### Summary

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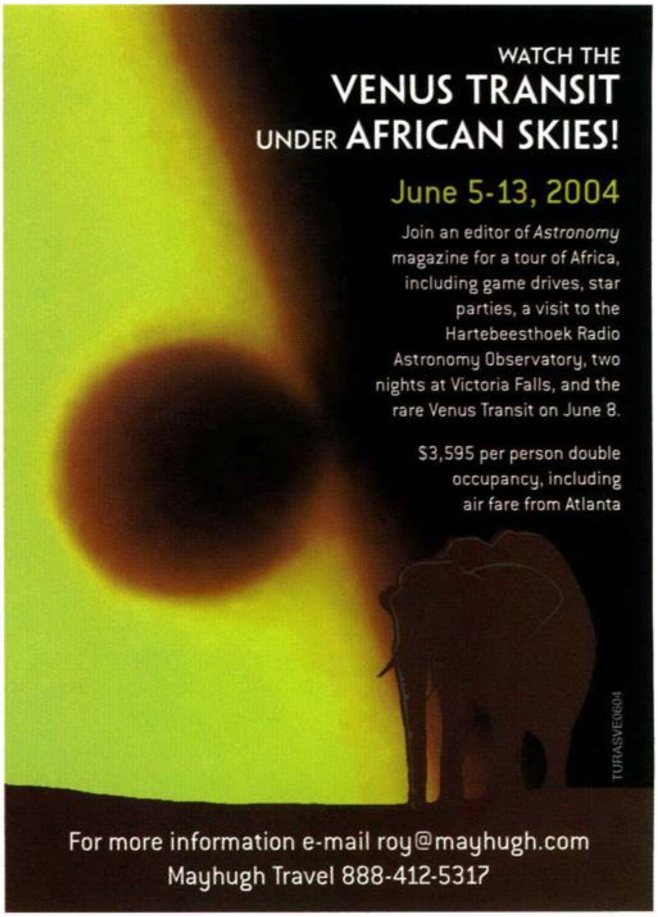

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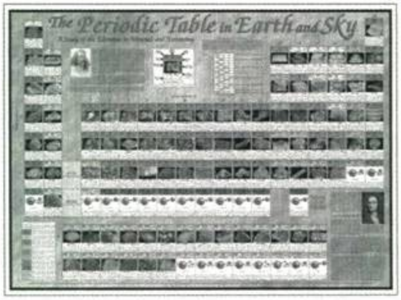

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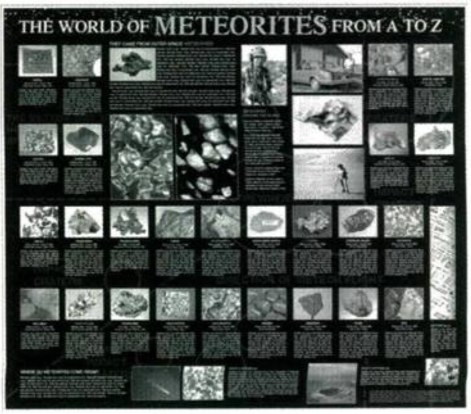

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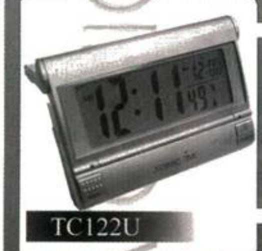

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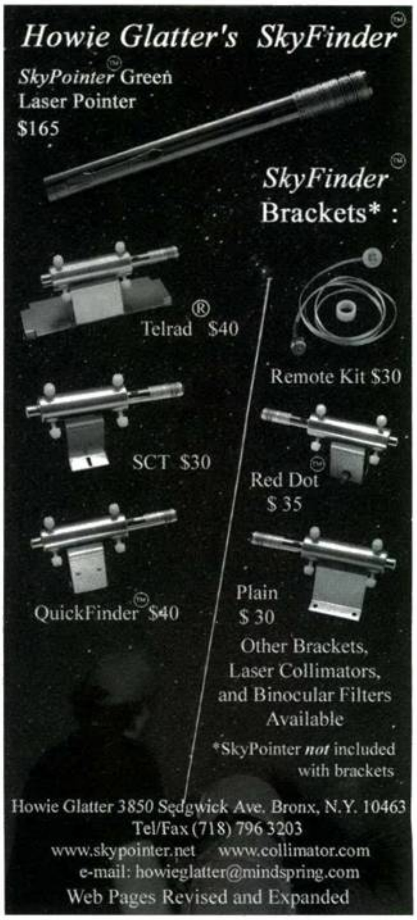

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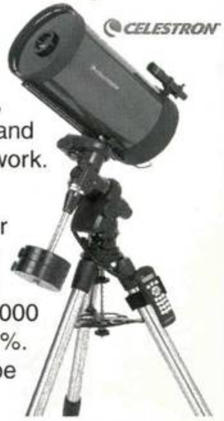

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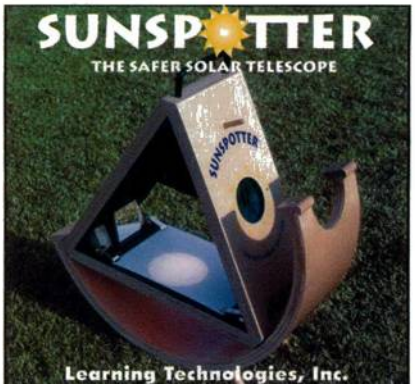

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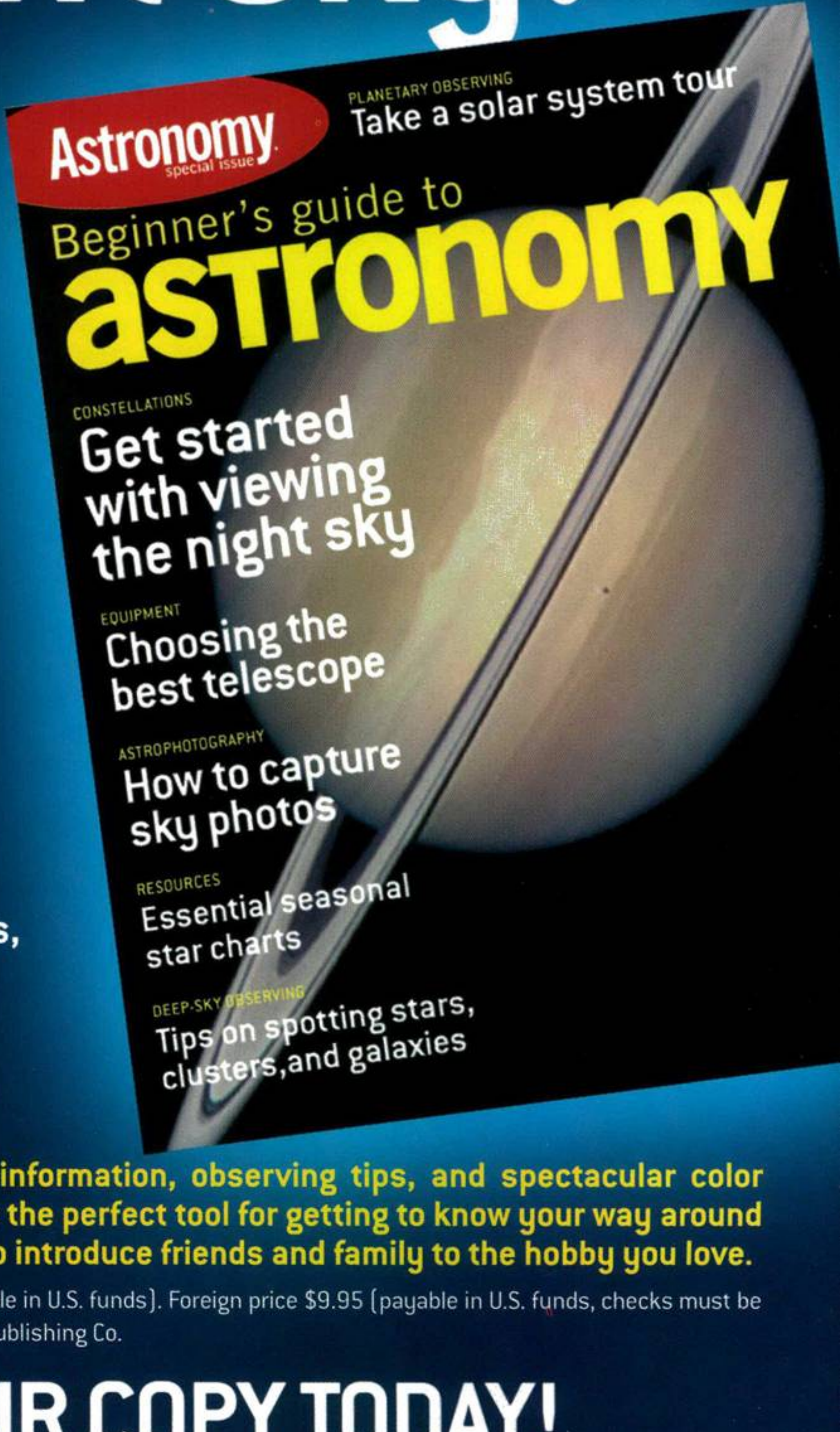

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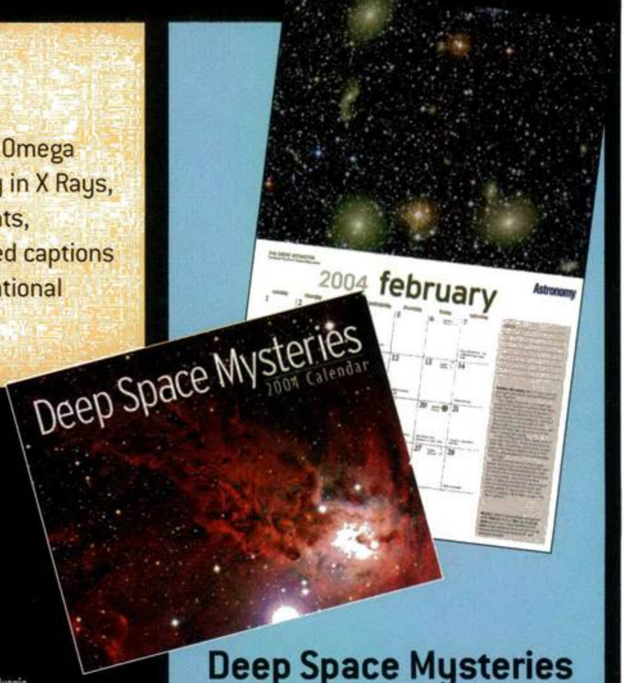

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# The year's best astronomy books

This reading list gives astronomy lovers 22 more reasons to stay up all night. /// BY FRANK SIETZEN, JR.

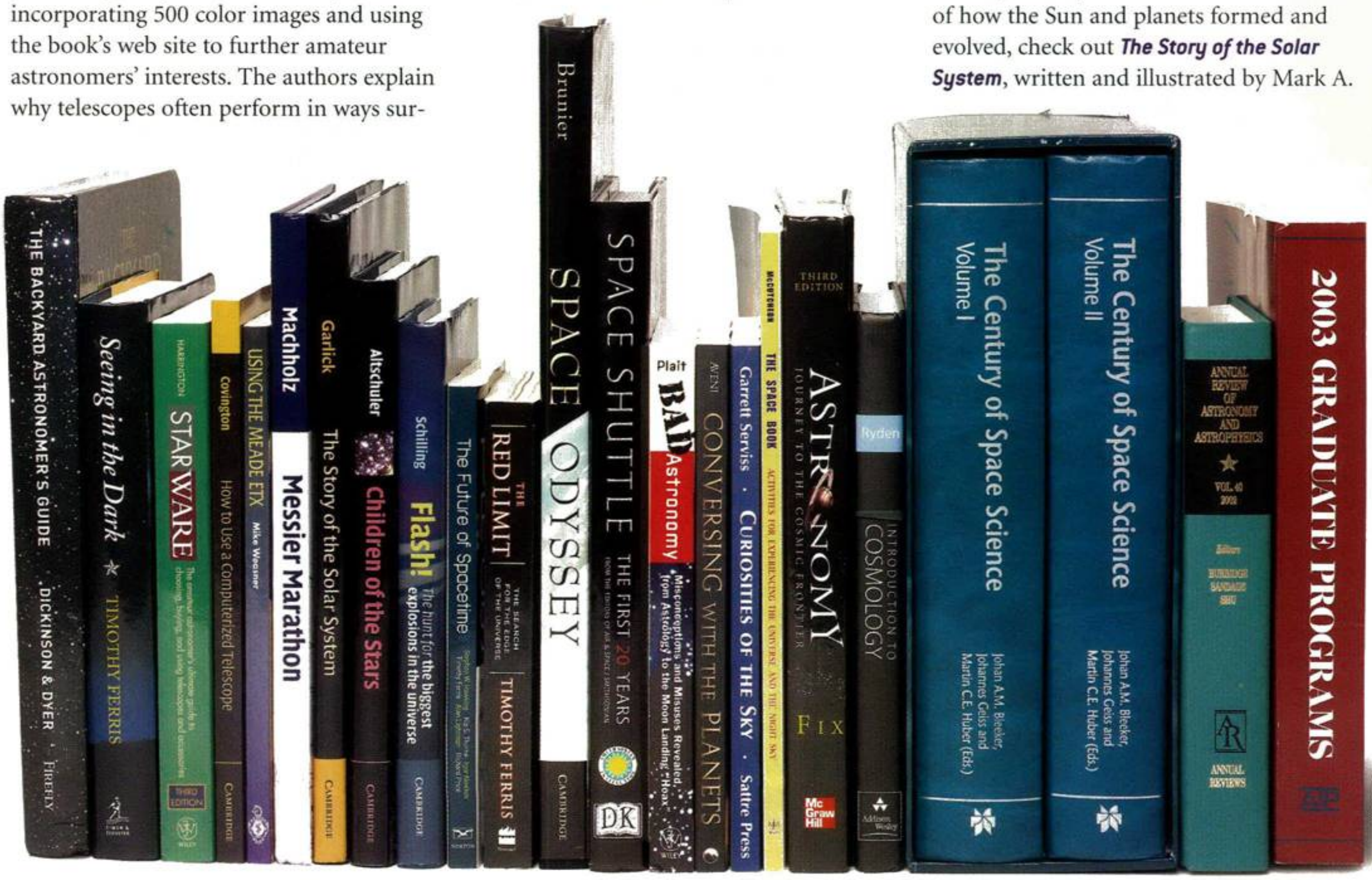
With the torrent of scientific results that constantly floods the media, it may be time to update your library with a few books that put the new findings in perspective. Here are 22 suggestions that do just that. Whether they're for the coffee table or the classroom, these offerings remind us that the story of the universe is a work in progress and that we are extraordinarily fortunate to live at a time when the unknown is so steadily becoming known. Nearly every day, fresh discoveries challenge our long-held notions of the cosmos.

Keeping pace with new technologies is the reason for the latest revision of ***The Backyard Astronomer's Guide*** by Terence Dickinson and Alan Dyer (Firefly Books, Buffalo, New York, 2002). This edition has been completely rewritten and updated, incorporating 500 color images and using the book's web site to further amateur astronomers' interests. The authors explain why telescopes often perform in ways surprising to the novice and give essential information on what to look for when shopping for astronomical equipment.

Staying in the backyard, Timothy Ferris champions amateurs in his latest offering, ***Seeing in the Dark: How Backyard Stargazers Are Probing Deep Space and Guarding Earth from Interplanetary Peril*** (Simon & Schuster, New York, 2002). In it, he charts how hobbyists have been racking up discoveries worthy of professionals through careful observation and by using the Internet to link their efforts.

In order to make similar contributions, you'll need the right tools. An excellent guide to astronomical equipment is the third edition of ***Star Ware*** by Philip S. Harrington (John Wiley & Sons, New York, 2002). This book looks beyond advertisers' hype and provides a comprehensive review of what you need and why. More advanced amateurs can learn to maximize their investments in go-to scopes with Michael Covington's ***How to Use a Computerized Telescope*** (Cambridge University Press, New York, 2002). Also see Mike Weasner's ***Using the Meade ETX: 100 Objects You Can Really See with the Mighty ETX*** (Springer-Verlag, New York, 2002), which includes observing tips and instructions on how to use features such as Autostar. Don Machholz's ***The Observing Guide to the Messier Marathon: A Handbook and Atlas*** (Cambridge University Press, New York, 2002) gives readers more than 90 star maps to guide observations of the 110 objects in the Messier Catalog.

To ground yourself in the latest theories of how the Sun and planets formed and evolved, check out ***The Story of the Solar System***, written and illustrated by Mark A.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2003 GRADUATE PROGRAMS

Garlick (Cambridge University Press, New York, 2002). Daniel R. Altschuler's ***Children of the Stars: Our Origin, Evolution and Destiny*** (Cambridge University Press, New York, 2002) gives readers Earth's story — past, present, and future. Along the way, Altschuler addresses climate change and other ecological and geological issues affecting our home planet.

The English translation of Govert Schilling's ***Flash!: The Hunt for the Biggest Explosions in the Universe*** (Cambridge University Press, New York, 2002) looks beyond the solar system at the latest gamma-ray burst research. ***The Future of Spacetime*** (W. W. Norton & Co., New York, 2002), with essays by Stephen Hawking, Kip Thorne, Igor Novikov, Timothy Ferris, Alan Lightman, and Richard Price, came out of a series of talks at the California Institute of Technology on such varied topics as time travel and the popularization of science. Ferris also revised and updated his 1977 book, ***The Red Limit: The Search for the Edge of the Universe*** (William Morrow & Co., New York, 2002).

Coffee-table books published last year include ***Space Odyssey: The first forty years of space exploration*** by Serge Brunier (Cambridge University Press, New York, 2002) and ***Space Shuttle: The First 20 Years***, edited by the staff of *Air & Space/Smithsonian* magazine (DK Publishing, New York, 2002).

In ***Bad Astronomy: Misconceptions and Misuses Revealed, from Astrology to the Moon Landing "Hoax"*** (John Wiley & Sons, New York, 2002), Philip Plait roots out and corrects common misunderstandings about astronomical events. Legend is the subject of the revised edition of ***Conversing with the Planets: How Science and Myth Invented the Cosmos*** by Anthony Aveni (University Press of Colorado, Boulder, Colorado, 2002). The 1909 classic ***Curiosities of the Sky*** (Sattre Press, Decorah, Iowa, 2002) has been updated and annotated by Sattre Press's publisher, William McClain, while preserving journalist Garrett Putnam Serviss's wonderment over celestial phenomena from aurorae to zodiacal light.

This year has seen some excellent resources for students from grade school to grad school. Marc McCutcheon's ***The Space Book: Activities for Experiencing the Universe and the Night Sky*** (John Wiley & Sons, New York, 2002) gives young readers 128 pages of hands-on activities, which include building everything from rockets to model atmospheres. John D. Fix's textbook, ***Astronomy: Journey to the Cosmic Frontier,*** 3rd ed. (McGraw-Hill, New York, 2003), lays out the subject for beginners. It's supplemented by a CD-ROM that includes planetarium software, animations, and quizzes. Barbara Ryden bolsters her ***Introduction to Cosmology*** (Addison Wesley, New York, 2003) with the latest observations. A massive and detailed astronomy text is ***The Century of Space Science***, 2 vols., edited by Johan A. M. Bleeker, Johannes Geiss, and Martin C. E. Huber (Kluwer Academic Publishers, Boston, 2001). Sixteen articles summarize research on such subjects as giant planets, binary stars, and planetary nebulae in ***Annual Review of Astronomy and Astrophysics, Volume 40, 2002***, edited by Geoffrey Burbidge, Allan Sandage, and Frank H. Shu (Annual Reviews, Palo Alto, California, 2002).

If these books have whetted your appetite to learn more, the American Institute of Physics's ***2003 Graduate Programs in Physics, Astronomy, and Related Fields*** (American Institute of Physics, College Park, Maryland, 2002) could be your road map to more structured study.

Whether it's in the classroom or the backyard, these titles will help you understand the celestial surprises yet to come. ◼

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**Frank Sietzen, Jr.** *is editor-in-chief of* Ad Astra *magazine and a writer and analyst specializing in space flight. He lives in Arlington, Virginia.*

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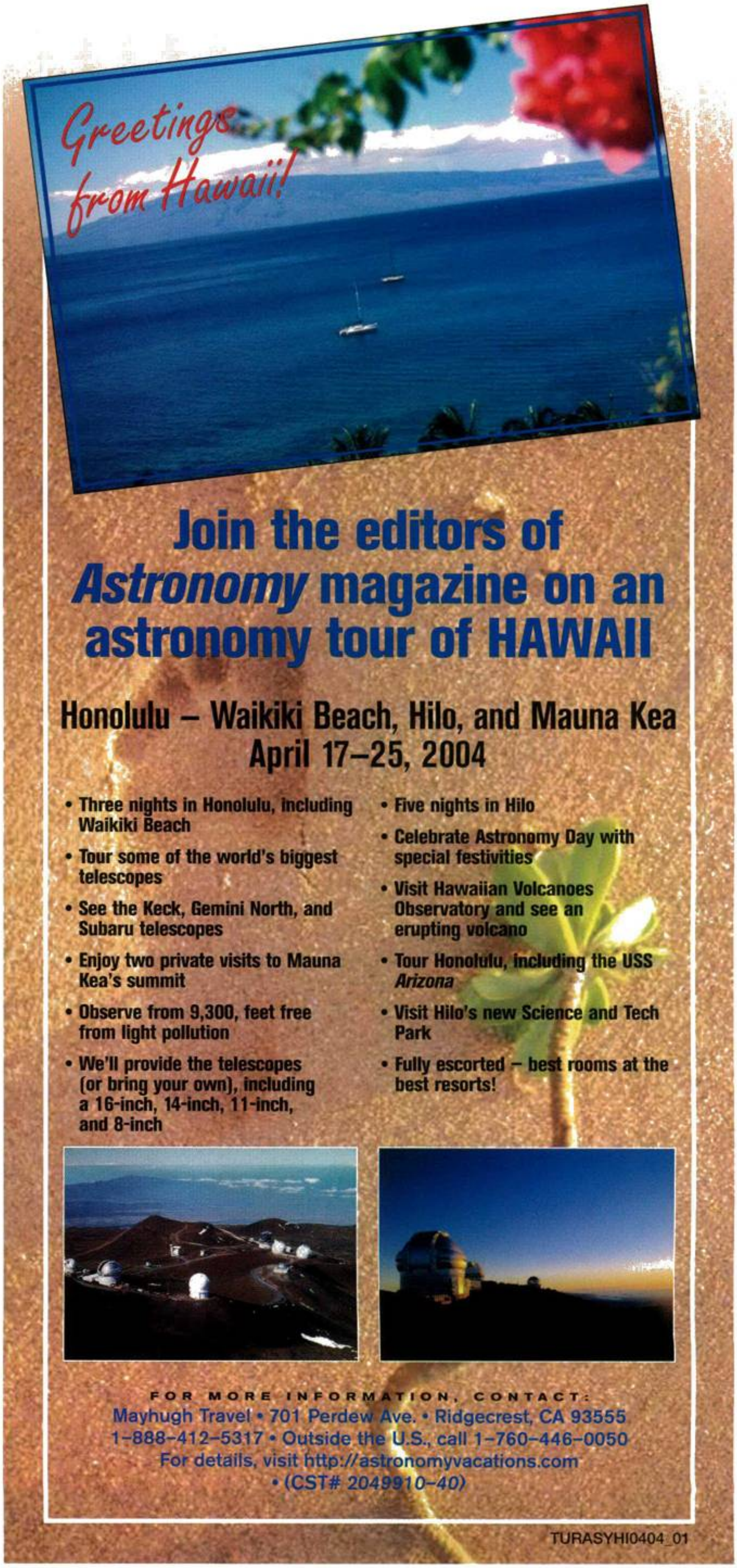

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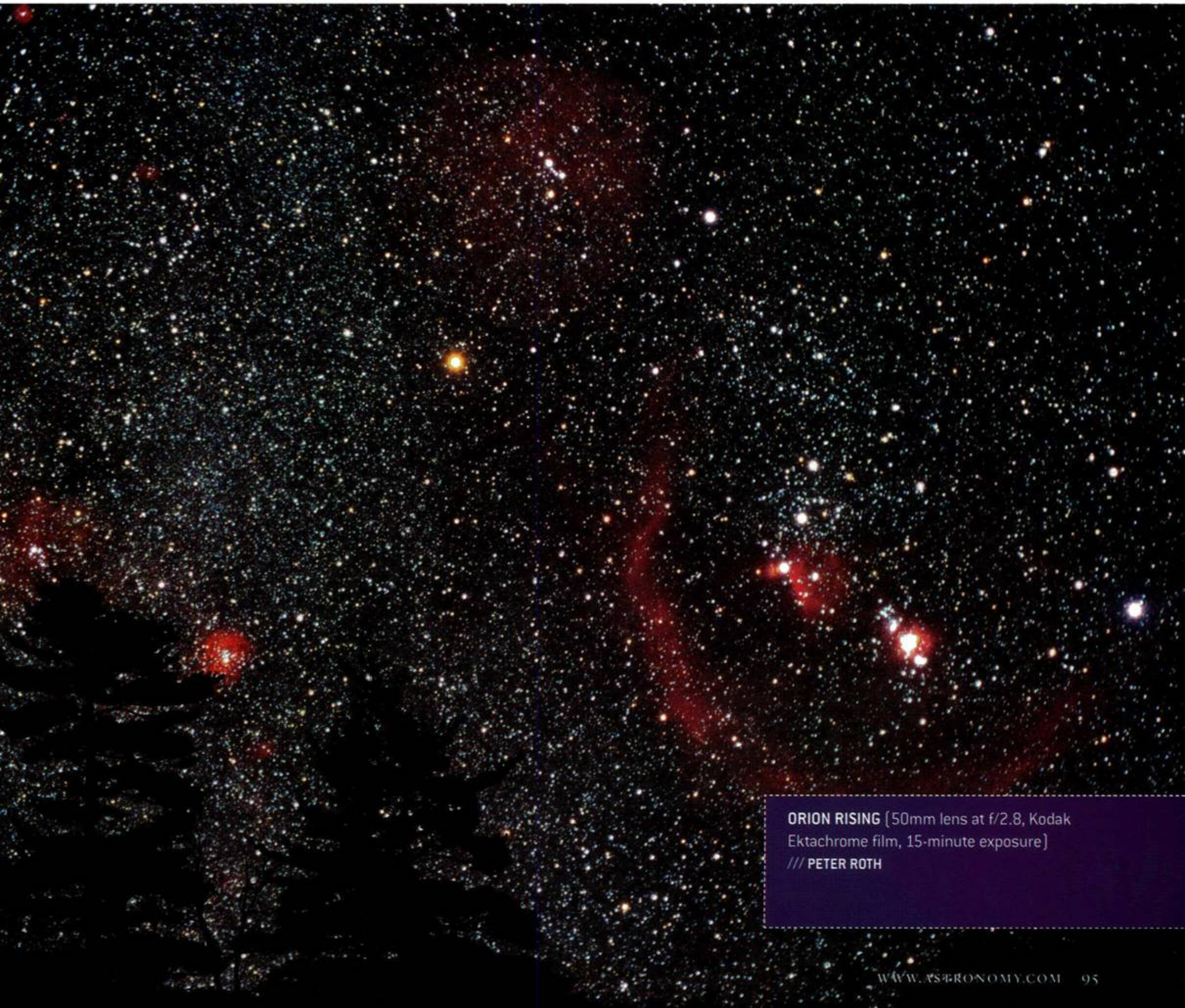
# Venturing into the beautiful universe

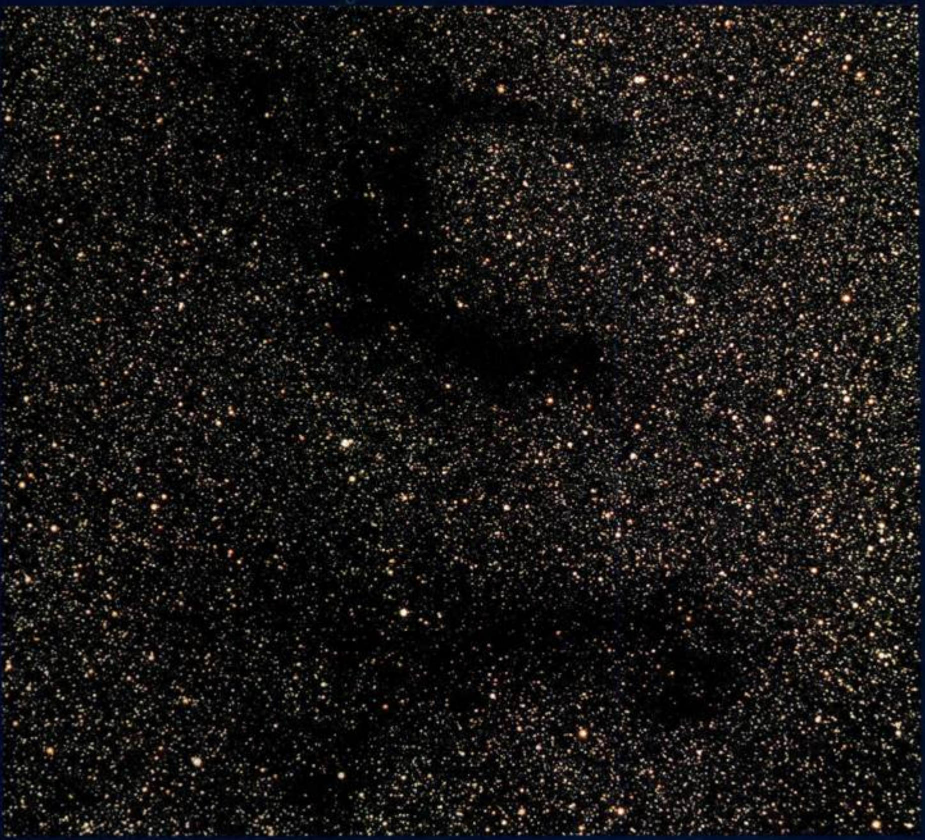
## Orion rising

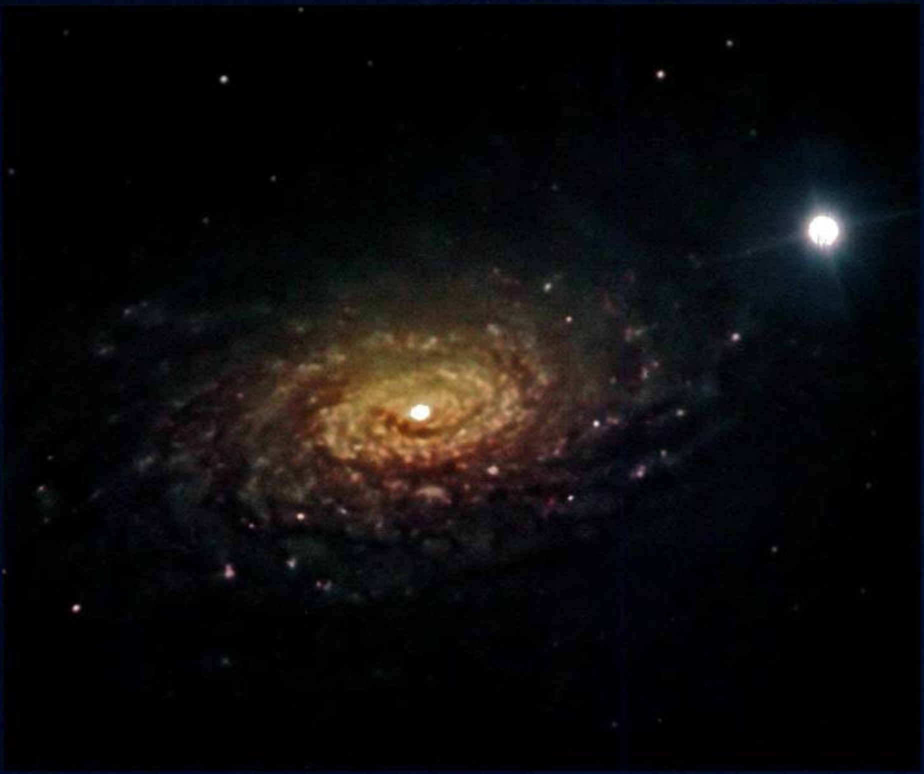
Orion is the favorite constellation of many observers because of the deep-sky objects in and around it. Center right, the Orion Nebula (M42) is seen as a bright, fuzzy spot. To its upper left, the reddish region around Zeta (ζ) Orionis is visible. Between the two trees (left), the Rosette Nebula (NGC 2237) shines, and to its upper left is the larger region of the Cone Nebula (NGC 2264). Both lie within the constellation Monoceros the Unicorn. The huge red "C" that surrounds the Belt is called Barnard's Loop, a vast cloud known as an emission nebula.

Two brilliant stars — coppery Betelgeuse (left of center) and blue-white Rigel (lower right of center) — are examples of stars with different surface temperatures: Betelgeuse is a "cool" 3,000° F, and Rigel a blazing 50,000° F.



**ORION RISING** [50mm lens at f/2.8, Kodak Ektachrome film, 15-minute exposure]
/// **PETER ROTH**

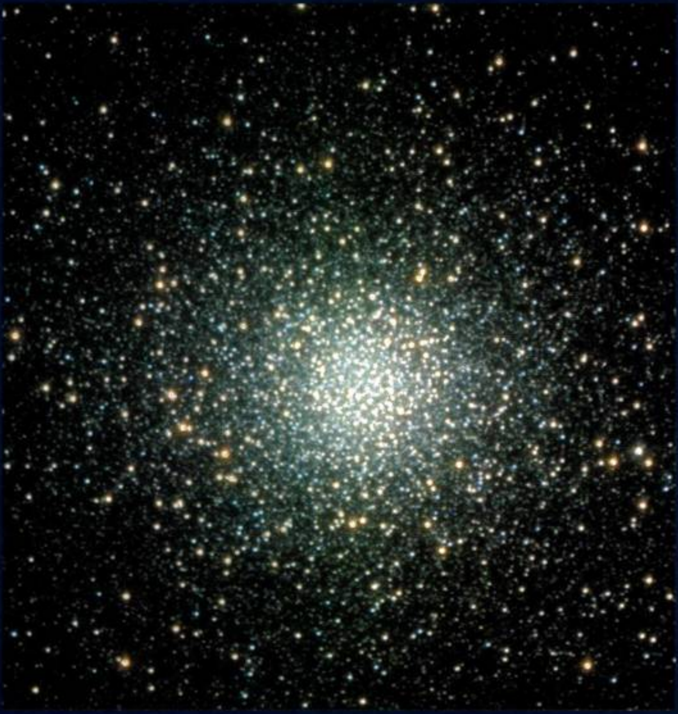


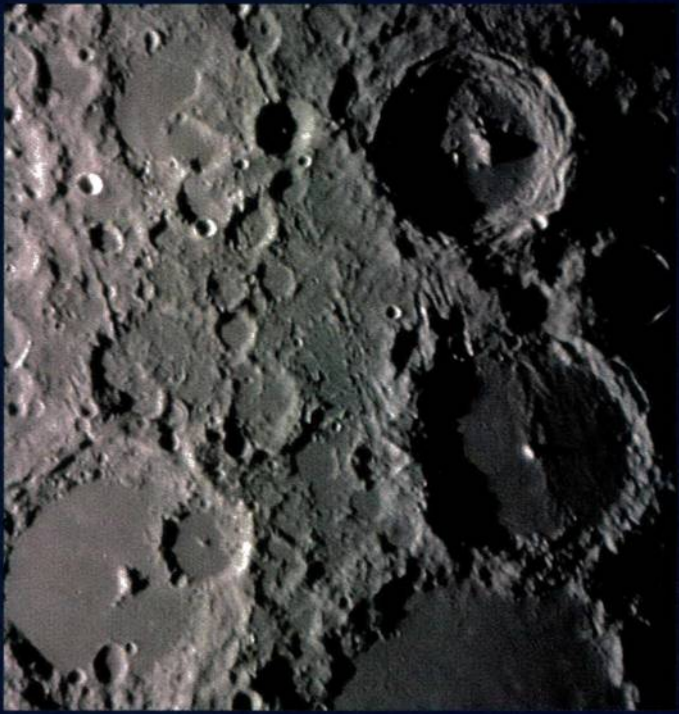


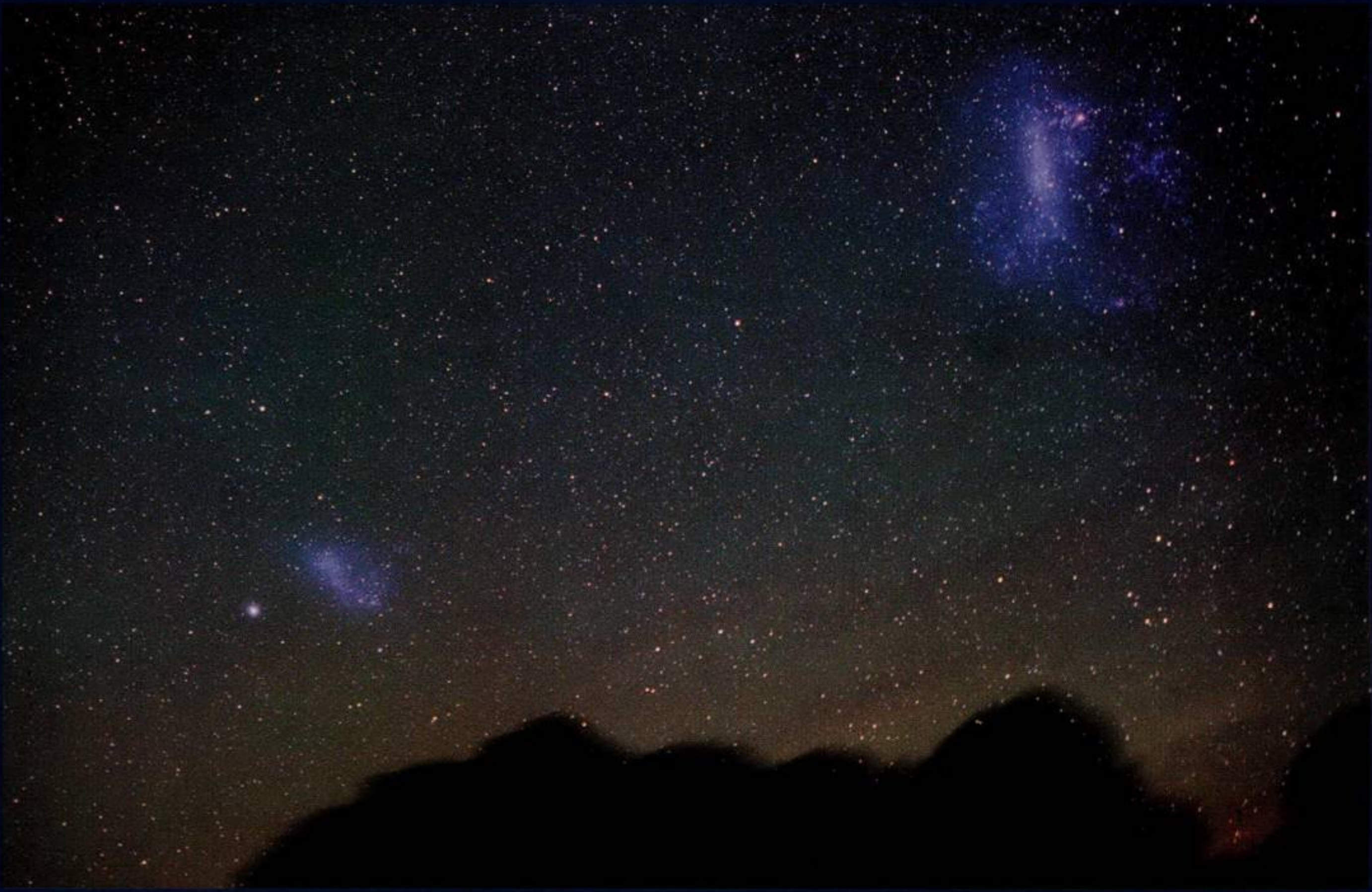
*Top.* **BARNARD'S E (B142 AND B143 IN AQUILA)** (Astrophysics 155mm f/7 EDF apochromatic refractor, Pentax 6x7 camera, Kodak PPF Pro 400 film, composite of two 50-minute exposures) /// **MICHAEL STECKER**

*Above.* **M63** (Optical Guidance Systems 12.5-inch Ritchey-Chrétien telescope at f/9, luminance [L] exposure of 240 minutes, and RGB exposures of 40, 40, and 70 minutes, respectively) /// **ROBERT GENDLER**

*Right.* **THE COCOON NEBULA (IC 5146)** (Astro-Physics 6-inch f/7 EDF apochromatic refractor, digital composite of two 45-minute exposures on hypered Kodak PPF Pro 400 film) /// **GEORGE GREANEY**



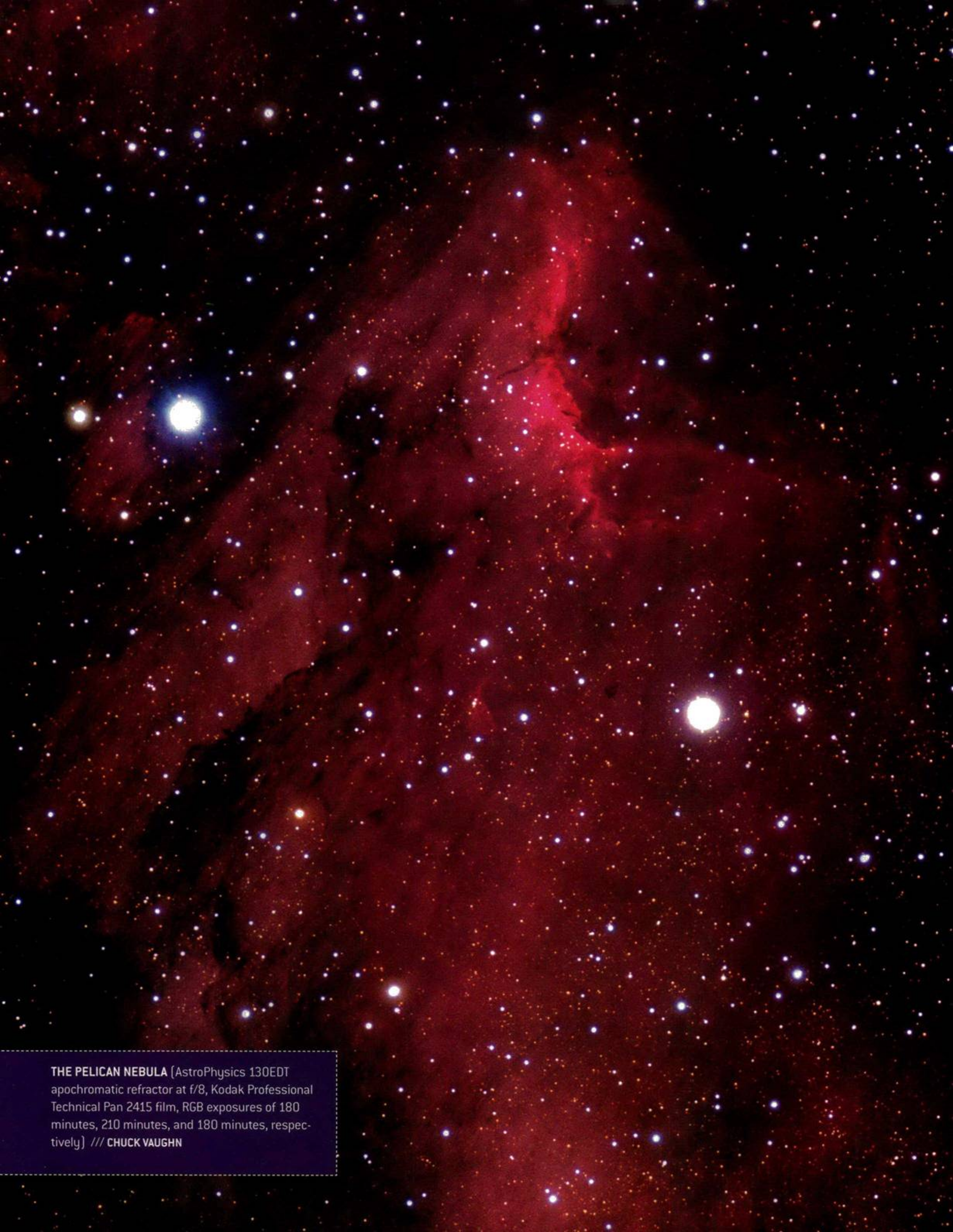




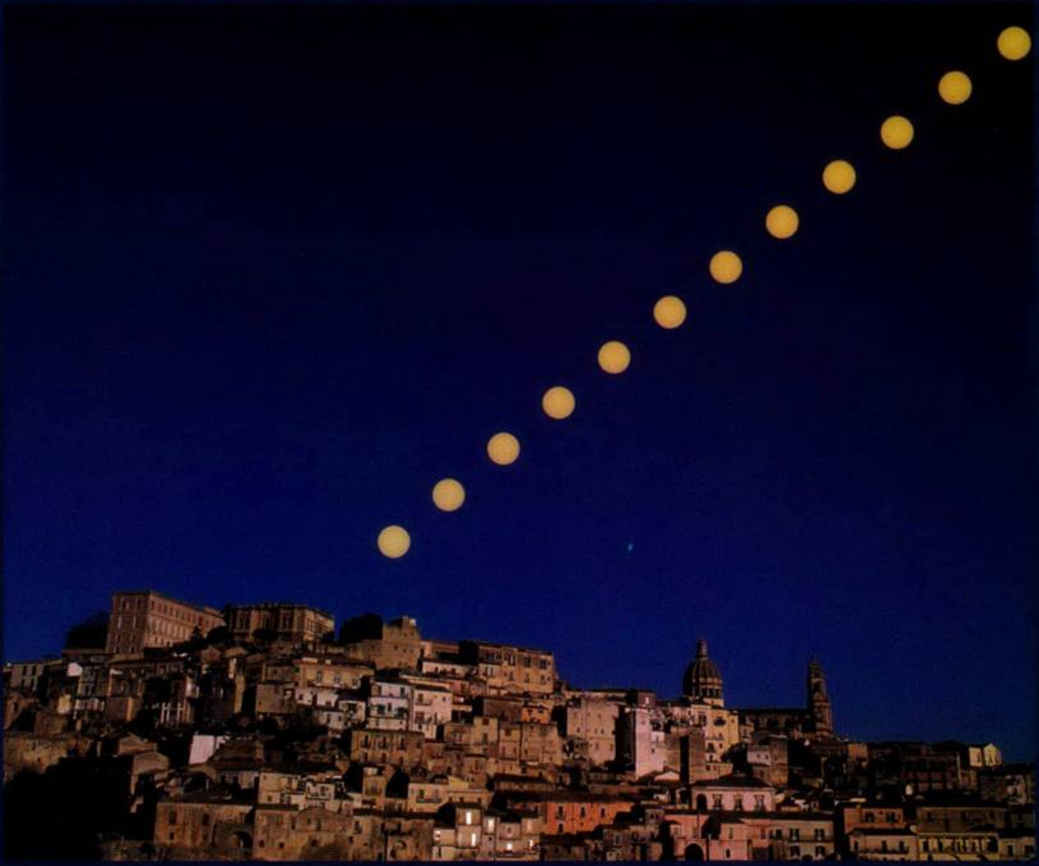
*Top left.* **GLOBULAR CLUSTER M5** [RC Optical Systems 16-inch Ritchey-Chretién scope at f/8, SBIG ST10XME CCD, luminance [L] exposure of 16 minutes, and RGB exposures of 8 minutes each] /// **SALLY AND CURT KING AND ADAM BLOCK**

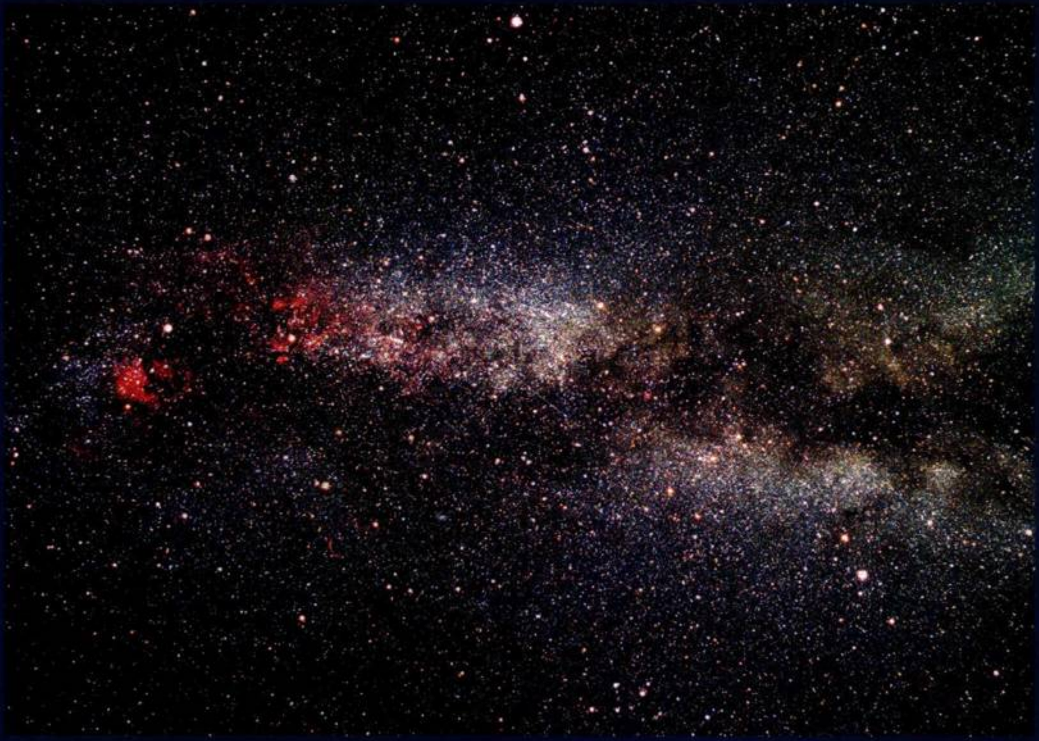
*Top right.* **ALBATEGNIUS, ALPHONSUS, AND ARZACHEL** [AstroPhysics 155mm refractor, Nikon Coolpix 950 digital camera, University Optics 18mm orthoscopic eyepiece, taken June 28, 2001, from Vernon, Virginia] /// **ARPAD KOVACSY**

*Above.* **THE MAGELLANIC CLOUDS** [Pentax 6x7 camera with a 90mm lens mounted on a Losmandy G11 driven equatorial mount, Kodak PMZ1000 film, 15-minute exposure] /// **MIKE MAYERCHAK**



**THE PELICAN NEBULA** (AstroPhysics 130EDT apochromatic refractor at f/8, Kodak Professional Technical Pan 2415 film, RGB exposures of 180 minutes, 210 minutes, and 180 minutes, respectively) /// **CHUCK VAUGHN**

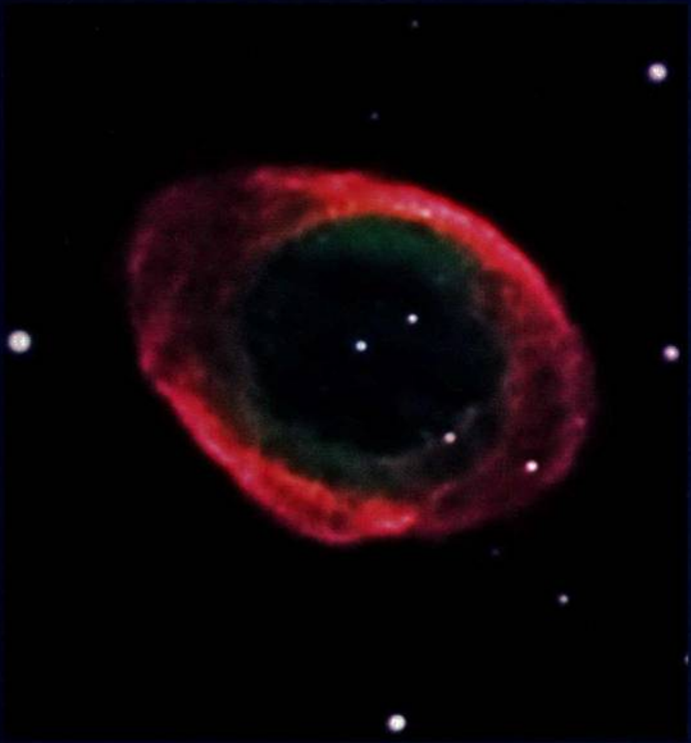


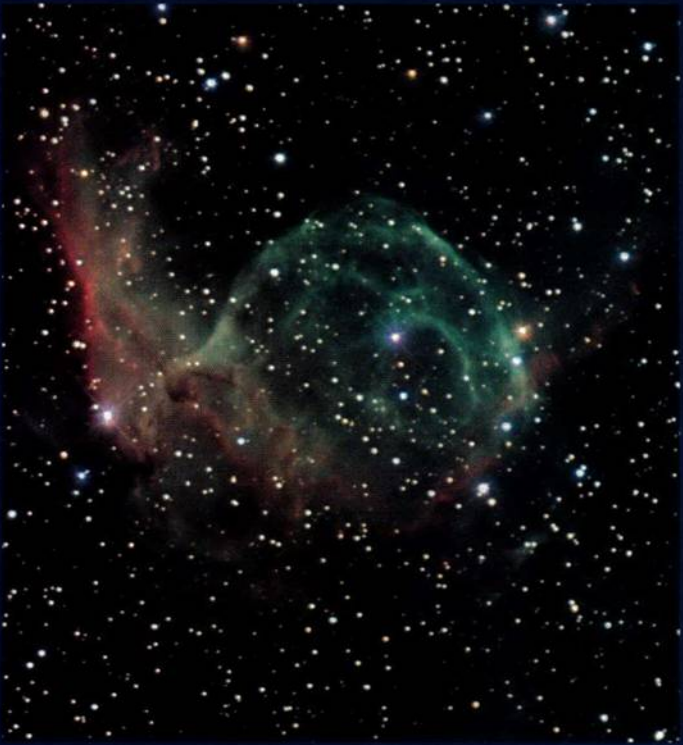


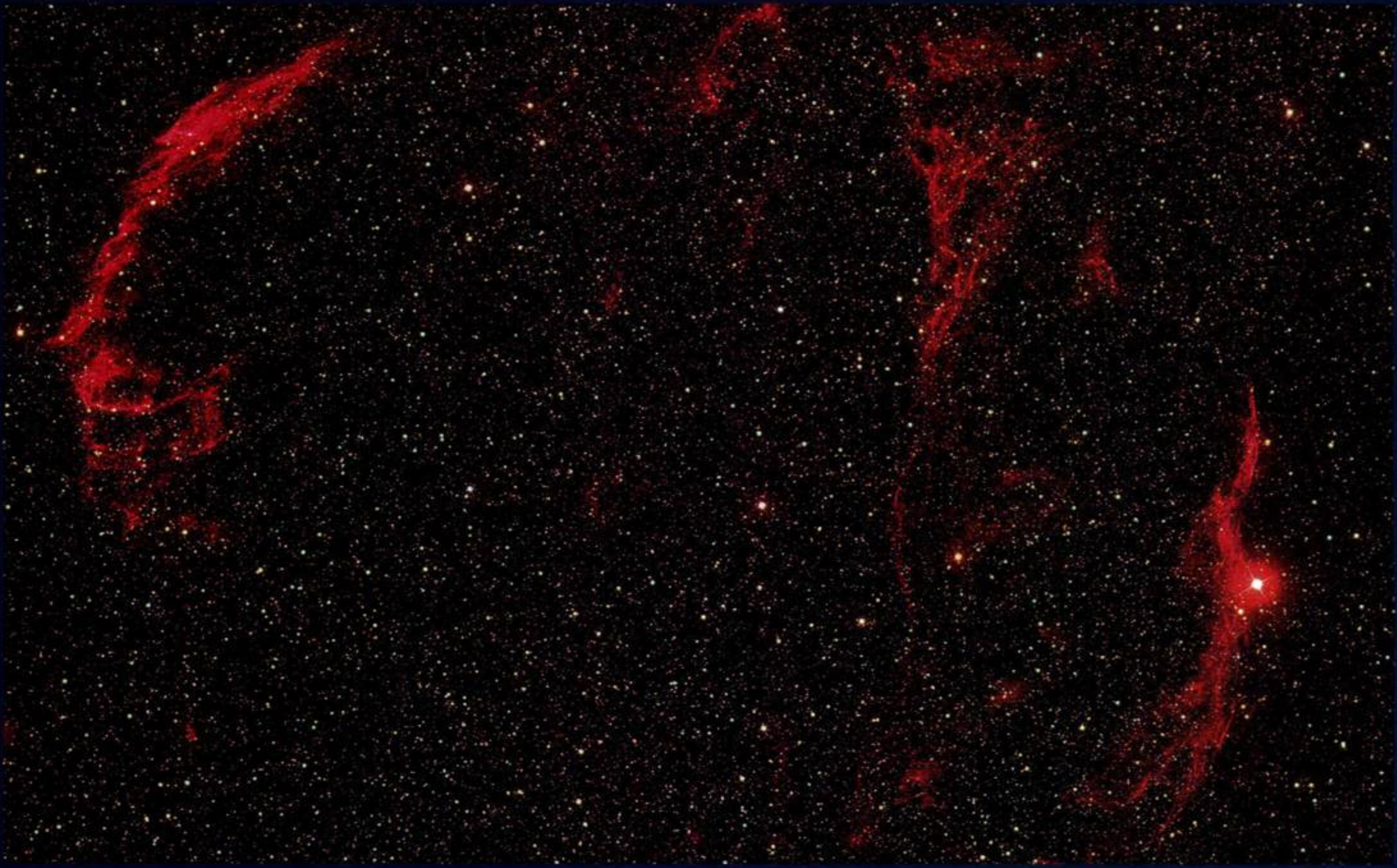
*Top.* **SUNRISE SEQUENCE** (one exposure with a 28mm lens at f/11, 1/125 second, 12 exposures with an 85mm lens at f/5.6, 1/60 second, through a Baader Astrosolar ND5 filter, taken every five minutes on February 7, 2003, from Ragusa, Sicily) /// **GIANNI TUMINO**

*Above.* **THE SUMMER TRIANGLE AND THE GREAT CYGNUS RIFT** (Nikon 35mm camera, 28mm lens at f/4, Kodak Ektachrome 200 film push-processed to ISO 800, 20-minute exposure on a driven equatorial mount, near Ragusa, Sicily) /// **GIANNI TUMINO**

*Right.* **NEBULOSITY SURROUNDING MEROPE** (Celestron 11-inch Schmidt-Cassegrain telescope at f/10, hypered Kodak PPF Pro 400 film, composite of two 60-minute exposures, taken November 28, 1997, from Mt. Pinos, California) /// **BOB AND JANICE FERA**



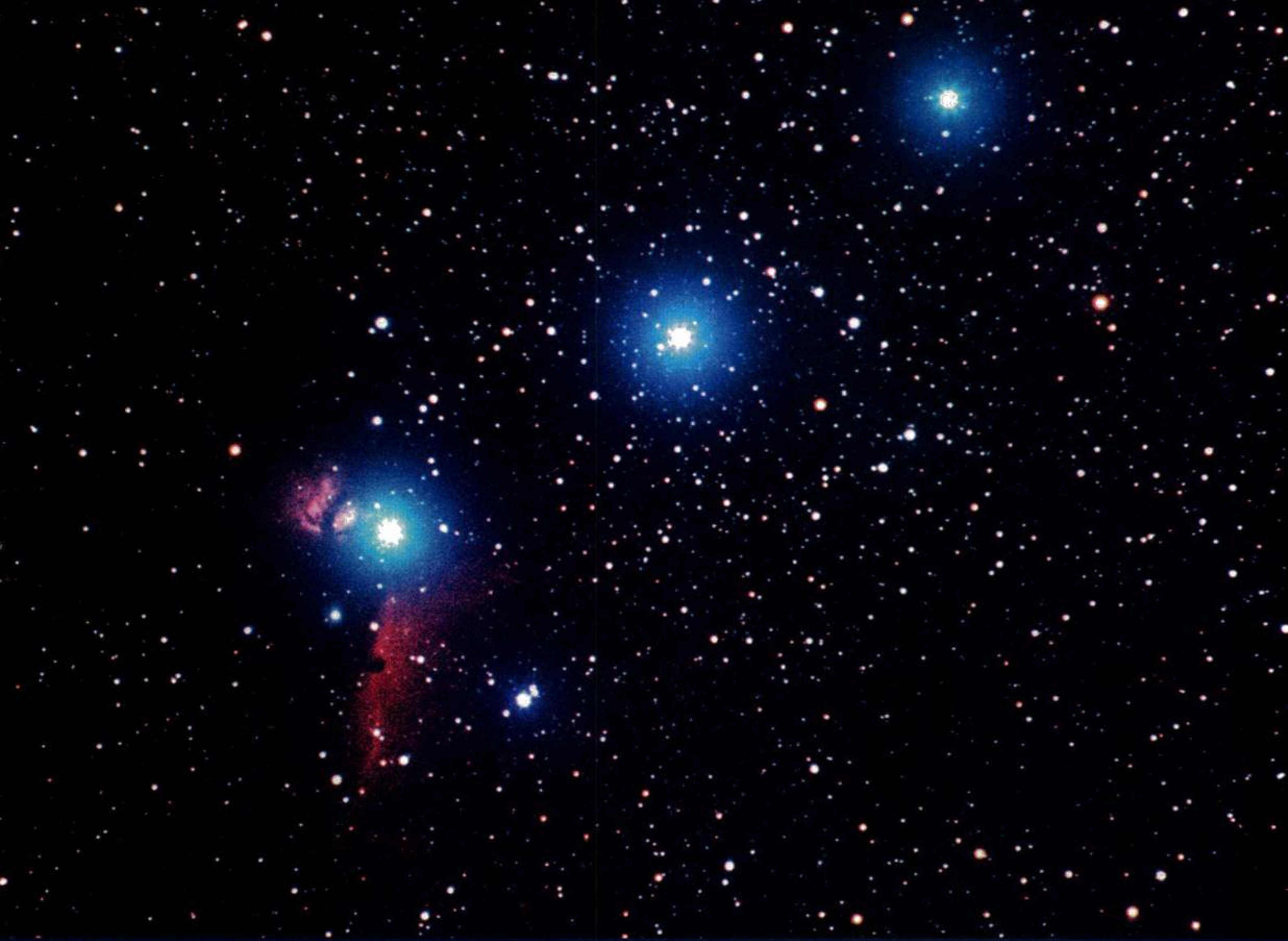


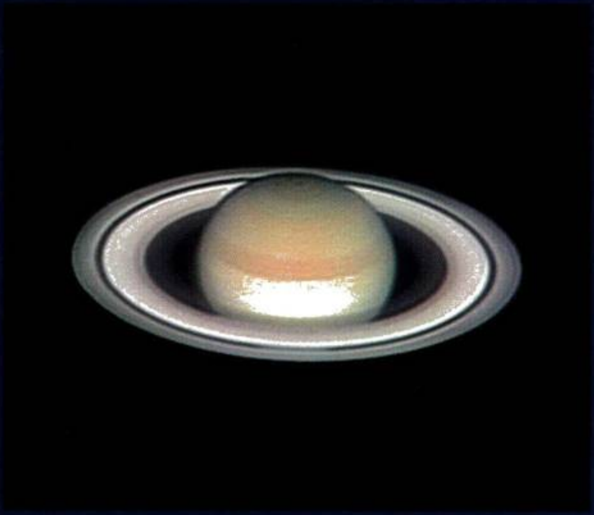


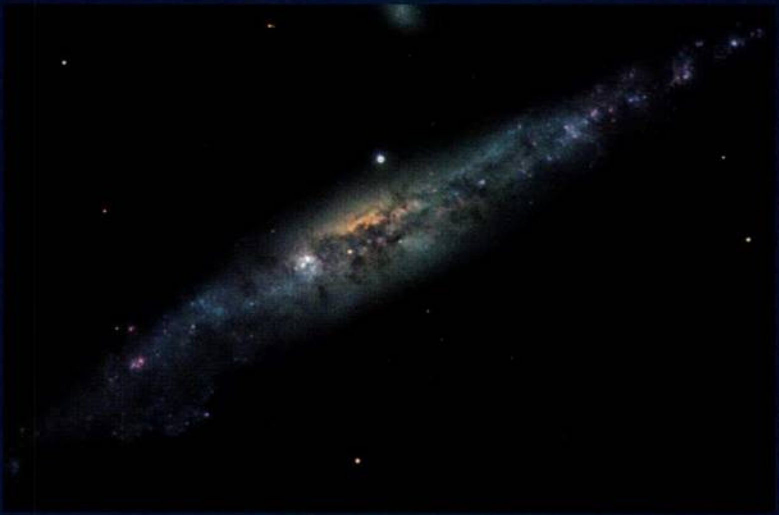
*Top left.* **THE RING NEBULA (M57)** [Optical Guidance Systems 12.5-inch Ritchey-Chrétien at f/9, SBIG ST10 CCD, luminance [L] exposure of 120 minutes, and RGB exposures of 10, 10, and 20 minutes, respectively] /// **ROBERT GENDLER**

*Top right.* **THOR'S HELMET (NGC 2359)** [RC Optical Systems 16-inch at f/8.8, SBIG ST10XE CCD, luminance [L] exposure of 60 minutes, and RGB exposures of 30 minutes each] /// **CHRISTINE AND DAVID SMITH, STEVE MANDEL, AND ADAM BLOCK**

*Above.* **THE VEIL NEBULA** [Meade 12/16-inch Schmidt Camera at f/2.2, Fujichrome 100 film, 60-minute exposure on a driven equatorial mount, taken from Plano, Texas] /// **JASON WARE**



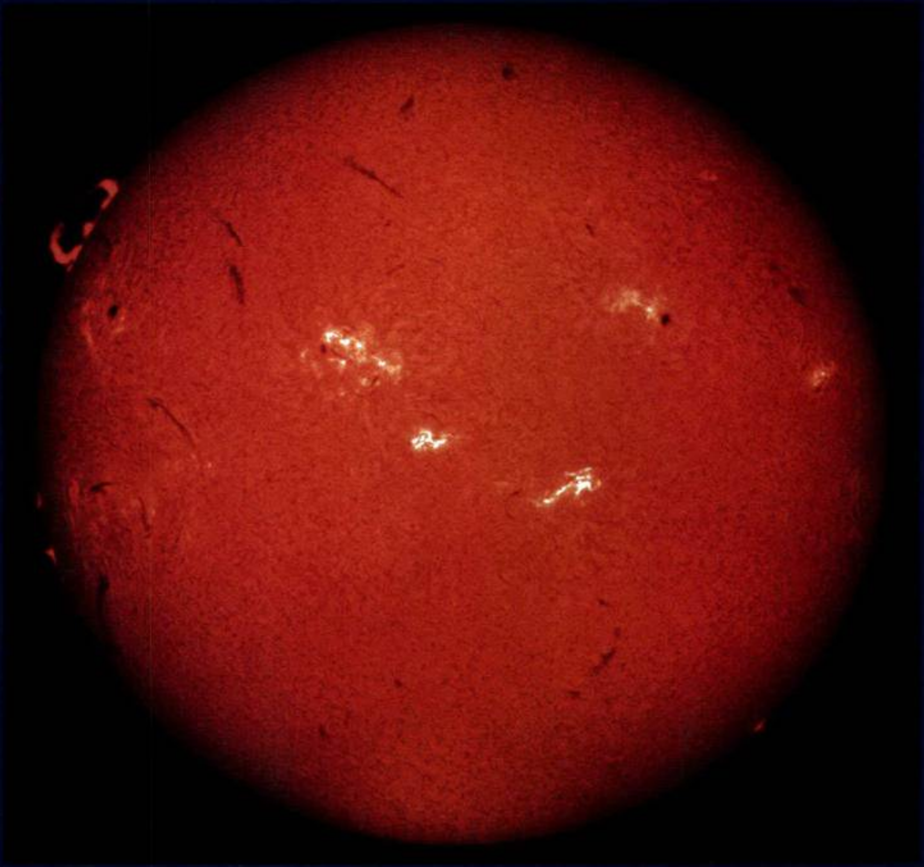




*Top.* **ORION'S BELT** (Canon 35mm camera on a driven equatorial mount, 300mm lens at f/8, Kodak Ektar 1000 film, composite of two 40-minute exposures taken near Ragusa, Sicily)
/// **GIANNI TUMINO**

*Bottom left.* **SATURN'S CREPE RING** (Celestron 14-inch Schmidt-Cassegrain telescope at f/68, SBIG ST6 CCD camera, taken November 19, 2001, from Houston, Texas)
/// **ED GRAFTON**

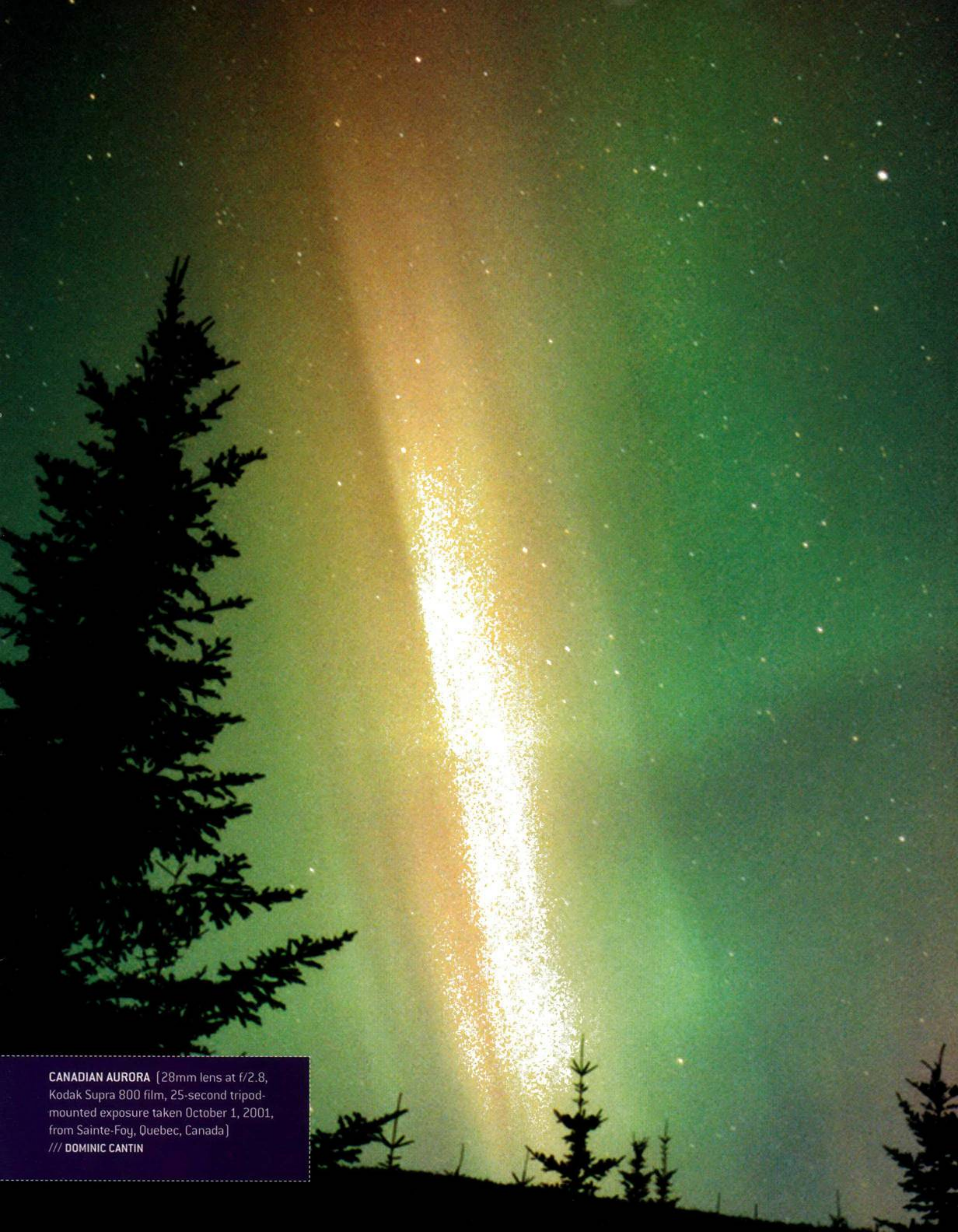
*Bottom right.* **THE WHALE (NGC 4631)** (Meade 16-inch LX200 at f/10, SBIG ST8E CCD camera, luminance (L) exposure of 60 minutes, and RGB exposures of 20 minutes each)
/// **SHANE LARSON, MIKE MURRAY, AND ADAM BLOCK**



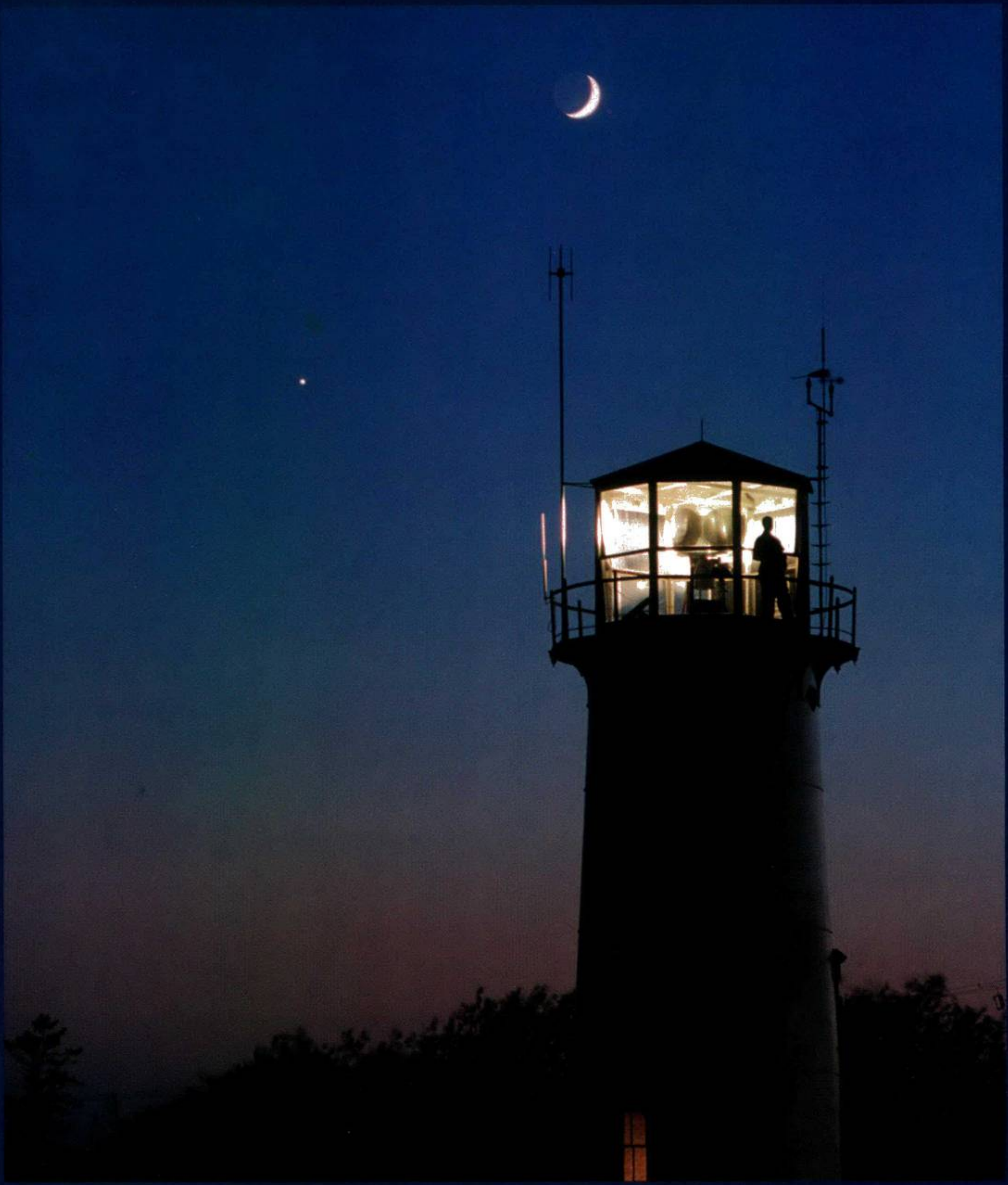
*Top,* **STAR CLOUD NGC 206 IN THE ANDROMEDA GALAXY** [14.5-inch custom-made classical Cassegrain telescope, SBIG ST10E CCD camera, taken from Foresthill, California]
/// **TONY AND DAPHNE HALLAS**

*Bottom left,* **GALAXIES M81 AND M82** [Meade 6-inch 152 ED apochromatic refractor at f/9, Fuji HG400 film, composite of two 60-minute exposures taken from Plano, Texas]
/// **JASON WARE**

*Bottom right,* **"BULL-HORN" PROMINENCES** [Daystar hydrogen-alpha filter, Kodak Tech Pan film, $\frac{1}{125}$-second exposure for disk detail and $\frac{1}{8}$-second exposure for prominences, taken March 29, 2003, from Apopka, Florida] /// **JEFF PETTITT**



**CANADIAN AURORA** [28mm lens at f/2.8, Kodak Supra 800 film, 25-second tripod-mounted exposure taken October 1, 2001, from Sainte-Foy, Quebec, Canada]
/// **DOMINIC CANTIN**



*Above,* **THE CRESCENT MOON AND VENUS OVER CHATHAM LIGHTHOUSE** [105mm lens at f/4, Fujichrome Provia 100 film, 3-second exposure taken August 11, 2002, from Chatham, Massachusetts] /// **CHRIS COOK**

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